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Contents

139 Horizontal education

140 Award of the Kelvin Medal

141 Parametric amplifiers
by C. W. OATLEY, O.B.E., M.A., M.SC., MEMBER

146 Symposium on data-handling and display systems for air traffic control

147 Printed-wiring techniques
by G. W. A. DUMMER, M.B.E., MEMBER

155 Meeting of the Council on the 4th February 1960

157 Problems and achievements of Électricité de France
by J. HARLEY, MEMBER

160 Wiring Regulations—recent interpretations

162 A review of the *Proceedings*, Parts A and B
(*details are given in the adjoining column*)

174 Correspondence

179 Obituary

180 Papers and monographs published individually this month
(*details are given in the adjoining column*)

182 Library accessions

182 District Meetings

183 Forthcoming events at Savoy Place

183 Contents of the current *Proceedings*

184 Elections and transfers

185 British Nuclear Energy Conference

186 Announcements to members

189 London report

191 Bulletin of the Sections

196 News from the Centres

198 News from abroad

BACK COVER **Index of advertisers**

162 A review of the *Proceedings*, Parts A and B

High-power transmitting valves with thoriated filaments	H. S. Walker, W. H. Aldous, R. G. Roach, J. B. Webb and F. D. Goodchild
V.H.F. field strengths over the Irish Sea	J. K. S. Jowett
Gaseous discharges in high-voltage d.c.-cable dielectrics	E. C. Rogers and D. J. Skipper
Vestigial-sideband signals from quadrature network	G. G. Gouriet and G. F. Newell
Rectifier modulators	D. P. Howson and Prof. D. G. Tucker
Field suppression of turbo-alternators	J. R. Hill, A. Hunt, W. J. Joyce and D. H. Tompsett
New valves for submarine telephone repeaters	M. F. Holmes and F. H. Reynolds
Amplitude and phase in v.h.f.-u.h.f. band	G. D. Monteath, D. J. Whythe and K. W. T. Hughes
Propagation of h.f. radio waves to long distances	F. Kift
Distortion of single-tone f.m.	R. G. Medhurst
A.C. operation of ion chambers at high fluxes	J. Watson
Impedance/frequency characteristics of glow-discharge reference tubes	F. A. Benson and P. M. Chalmers
Reignition voltages of freely recovering arcs	F. W. Crawford and H. Edels
Ferroresonant systems of circuit logic	Prof. J. G. Santesmases, M. Alique and J. L. Lloret
Reversed lag for on-off temperature control	H. Sutcliffe

180 Papers and monographs published individually this month

PAPERS

V.H.F. sound broadcasting	R. V. Harvey
Component selecting and testing machine	T. C. Cardwell, J. R. W. Smith and G. H. King
Henri de France colour-television system	R. Chaste and P. Cassagne
Pole-changing motor for crane-hoist drives	O. I. Butler and V. Ahmad

MONOGRAPHS

Trigatron spark-gap at very high voltages	T. E. Broadbent
Slot antennae	R. King and G. H. Owyang
Steady forces in variable-parameter networks	W. E. Smith
Zeros of a polynomial	O. P. D. Cutteridge
Effect of search-coil holes on flux	B. V. Jayawant
Orthogonal codes	H. F. Harmuth

Hydroelectricity in France

OVER half the electricity generated in France is now derived from hydroelectric power stations, almost all of which are located in the mountainous south.

The cover picture this month shows vehicles conveying river-bed materials with which the Serre Ponçon dam on the river Durance is constructed. This method of building necessitates the installation of a vertical screen, impervious to water, in these materials. The river bed was porous, and until modern equipment recently became available it was not possible to drill the 360ft necessary to reach bedrock and also to penetrate the bedrock. The power station and tail-race have been tunnelled into solid rock.

Other achievements of Électricité de France, including developments in h.v. transmission and load-factor improvement, are discussed by Mr. J. Harley in his article which starts on p. 157

Secretary W. K. BRASHER, C.B.E., M.A., M.I.E.E. *Editor* W. G. ASKEW, M.C.
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JOURNAL

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SAVOY PLACE LONDON W.C.2 VOLUME 6 NUMBER 63 MARCH 1960

HORIZONTAL EDUCATION

INDUSTRY'S role in the life of the state is daily becoming greater. Its influence is reaching, often without its own will being engaged, into the multifarious activities of Government, and it is emerging in the 1960's as one of the pillars of our whole national life.

Some may therefore find it mildly intriguing when this Colossus among us is appealed to to take an active part in an enterprise for something so closely entwined with its vital interests as technical education. Be that as it may, there will be widespread approval for the appeal by Sir Alexander Fleck, with the support of the Minister of Education, for the establishment of a residential staff college for senior teachers in educational institutes of technology and commerce and senior industrial staff.

Sir Alexander asks industrial and commercial firms to give £100000 as a single, once-and-for-all contribution, of which £60000 has already been promised. The running costs, about £30000 a year, will be paid mainly from public funds. It seems, therefore, that the financial provision may be assured.

What of the more inaccessible provision—the atmosphere in which a free and friendly traffic of ideas and experience can flourish?

The staff college is intended to provide a centre where the senior staff from all types of college giving technical and commercial education and senior representatives of industrial and commercial firms and others with similar interests can exchange ideas and experience. To establish such a staff college was among the recommendations of the Willis Jackson Committee on the Supply and Training of Teachers for Technical Colleges.

That Committee felt there was a need at the top level of the technical teaching profession for men with the breadth of outlook, attitude of mind and authority necessary to exert a strong influence both within their own colleges and on the industrial and commercial organizations which they serve.

A small staff college is envisaged, offering a series of 2–4-week courses throughout the year. It is hoped that the first course will begin before the end of 1961. Each course would have some 30 members, about two-thirds teachers and the rest industrial education and training officers, personnel managers, works managers, research, production and sales staff, school and university staff, and so on. So far, so good, but it is to be hoped that a strict interpretation will be applied to the word 'senior'. Many such ventures start with the best of intentions and then find that, when the 'fashionable' lure has worn off, the level of seniority of the participants declines and the organization becomes a hive of banality, a talking-shop without authority.

This is not to imply that the staff college itself should claim such authority. It is rather that, if its course members have little authority to translate words and intentions into action over a period of years, the college will be an amiable and ineffective addition to our educational apparatus.

It is anticipated that the college would be a self-governing entity, with its own governing body consisting of representatives of industry and commerce, of local education authorities and teachers. The governing body would be responsible for the buildings, the appointment of staff, the programme of courses, administration, finance and general policy.

The local authorities would be responsible for about half of the annual running costs, so that the Minister's observation that the success of this 'wholly new departure' must depend on 'the full and whole-hearted support of the local authorities who employ the teachers and of industry' deserves emphasis.

What of the content of the courses? Each course would be devoted to some different major topic of concern to the technical colleges relating to the development of teaching methods, the establishment of new courses, the emergence

of new technologies, and the administration and organization of the colleges. There would be no 'instruction' in these subjects. The participants would come to pool their ideas and experience and to learn from one another. But there would, of course, be a nucleus of permanent staff, headed by a director of studies.

This is the point where one's understanding of the scheme needs to be clarified. It would be unfortunate if the impression were given that concentration would be only on what the technical colleges can do to help meet the challenge of the times.

Sir Willis Jackson, in his Presidential Address last October, spoke in terms of a true partnership between industry and the technical colleges, a partnership which makes demands on each and in which a two-way traffic of co-operation exists. He asked for industry's closer collaboration with the technical colleges in the encouragement of its apprentices to participate in courses; he referred to the integration of academic study and industrial training; he stressed the necessity for the lively participation of senior industrial representatives in the advanced teaching work and in the government of technical colleges. He stated 'it is quite unrealistic to suppose that the teaching of technology at its highest level can be carried wholly by men who occupy full-time teaching posts unless these men return to industry or a similar environment at appropriate intervals'.

His remarks lead us to a wide view, to a vision of a staff college where a true two-way market of experience prospers, where the exchange of ideas leads to constructive action both in the technical colleges and in industry. We are confident that this will happen and that the governing body of the staff college will emphasize in the terms of reference of its courses the principle of the two-way transaction and of the industrial arrangements also coming under scrutiny and being the subject of fruitful discussion. The two partners are too mutually dependent for this not to happen.

The chartered electrical engineer would seem to have a special part to play in the furtherance of this spirit. In his professional capacity he bridges the gap between industry and education and stands already at the meeting place which the staff college is designed to contain.

Let us hope that this college will earn distinction and reputation. To adapt (barbarously) the words on The Institution's coat of arms to the function of the college, *Floreat Discedocena.*

AWARD OF THE KELVIN MEDAL

THE Kelvin Medal for 1959 was presented to Sir Geoffrey Taylor, F.R.S., at The Institution of Civil Engineers on the 16th February 1960.

In the course of his remarks before making the presentation, Prof. A. J. S. Pippard, F.R.S., referred to Sir Geoffrey's early studies of eddies in the atmosphere, his expedition to the North Atlantic in 1913, his aerodynamic research in the First World War, and his elucidation of problems connected with the propagation of shock waves in the earth and the physics of nuclear explosions in the Second World War. Prof. Pippard continued 'His work in meteorology and aerodynamics and his many contributions to hydrodynamics, to elasticity, to the behaviour of crystals under strain, to plastic flow in metals and to the mathematics of viscous and compressible fluids have firmly established his reputation as one of the greatest of applied mathematicians and mechanicians'.

Throughout a productive life of over half a century, Sir Geoffrey Taylor has produced a yearly average of three or four original scientific papers of outstanding quality. Cambridge University Press have already published one volume of his 'Collected papers' containing 40 which deal with the mechanics of solids. Another three volumes of the same size, devoted to the mechanics of fluids, are in preparation, and altogether the four will contain about 160 papers.

The Kelvin Medal is awarded triennially as a mark of distinction in engineering work or investigation of the kinds with which Lord Kelvin was especially identified. The President of The Institution of Civil Engineers is Chairman of the Award Committee, which consists of the Presidents for the time being of The Institutions of Civil, of Mechanical and of Electrical Engineers, The Royal Institution of Naval Architects, The Institution of Mining and Metallurgy, The Institution of Mining Engineers, The Institution of Engineers and Shipbuilders in Scotland, and The Iron and Steel Institute.

Previous recipients of the Medal have been:

1920 Dr. W. C. Unwin
1923 Dr. Elihu Thompson
1926 The Hon. Sir Charles Parsons
1929 M. André Blondel
1932 The Marchese Guglielmo Marconi
1935 Sir Ambrose Fleming
1938 Sir Joseph J. Thomson
1947 Air Comm. Sir Frank Whittle
1950 Dr. Theodore von Kármán
1953 Dr. Chalmers Jack Mackenzie
1956 Sir John Cockcroft

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PARAMETRIC AMPLIFIERS

This article is concerned with new types of microwave amplifier and frequency convertor which incorporate variable-reactance devices. Practical methods of realizing such devices are described and compared. The over-all performance of the new amplifiers in terms of bandwidth and noise factor is discussed and it is shown that they are likely to have important advantages over existing types.

The article is based on half of the lecture given by the author to the Electronics and Communications Section at Savoy Place on the 18th March 1959, the other half of the lecture being devoted to masers. A report of the meeting appeared in the May 1959 Journal, p. 336.

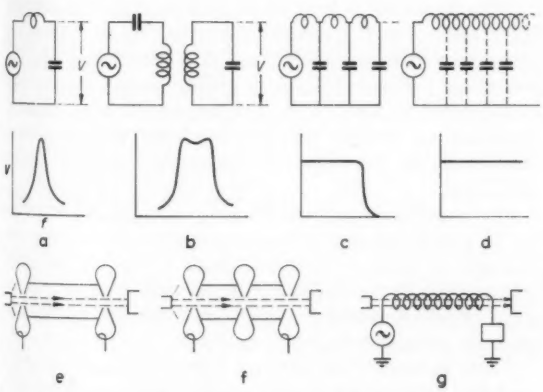
Mr. Oatley is in the Department of Engineering of the University of Cambridge.

C. W. OATLEY, O.B.E., M.A., M.SC., MEMBER

THE ever-growing importance of microwaves in all branches of electronics has led to intensive research on microwave receivers. For long-range radar a receiver with a low noise factor is most desirable, and this is also true for communication links using scatter propagation. In each case the high-power transmitter is likely to be extremely expensive and its cost will be increased if the receiver introduces appreciable noise. For communication links, bandwidth is almost equally important so that a single installation may provide a number of separate channels.

During the past few years two new classes of microwave receivers have been introduced which may be termed collectively *masers* and *parametric amplifiers*. In each class the underlying principle is quite different from that governing conventional receivers and the results already achieved are extremely promising. In the present article masers will not be considered, though this must not be taken to indicate that they are less important than parametric amplifiers: in fact they represent the more revolutionary development and may ultimately have greater potentialities.

The object here is to give an elementary account of the fundamental principles of parametric amplification and to put into perspective a number of separate lines of advance. Details of particular devices are not given and the names of the many workers who have contributed to these advances are not mentioned. It is however proper to say that almost all the basic work was done in the United States.



1 *Development of passive networks and microwave valves*

a single circuit
b coupled circuit
c low-pass filter
d distributed delay line
e two-cavity klystron
f three-cavity klystron
g travelling-wave tube

Relation of gain to bandwidth

It is convenient to review some well known facts relating to passive networks and conventional microwave valves in order to illustrate principles which apply equally well to the new devices.

Figs. 1a–1d refer to passive networks. Beginning with a single tuned circuit, if we require a reactive network which will pass a larger band of frequencies we turn successively to a pair of coupled circuits, a filter, and finally to a distributed filter or delay line.

Over the years we have seen a somewhat similar development in amplifiers using ordinary pentodes. Beginning with a single-stage tuned amplifier, we can get increased bandwidth by replacing the single tuned circuit by coupled circuits or by using a number of stages stagger-tuned. Finally to cover a very wide range of frequencies we can build a distributed amplifier.

More recently the evolution of microwave valves has followed a similar pattern (Figs. 1e–1g): the simple klystron has been followed by the multi-resonator klystron and the distributed amplifier that we know as the travelling-wave tube.

These analogies have of course been oversimplified but they do illustrate a general principle. With a single amplifying element we can usually adjust the ancillary circuits so that we get increased bandwidth at the expense of gain. This process clearly comes to an end when the gain has been reduced to unity. For still greater bandwidths we must add more amplifying elements and, in the limit, we shall probably find it advantageous to use some form of distributed structure.

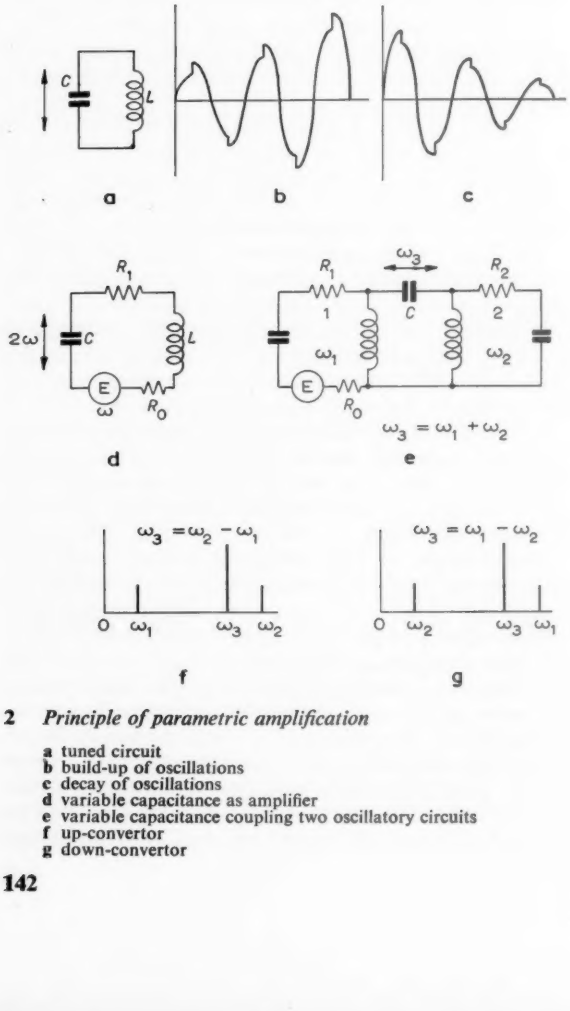
This general trend has been followed in nearly all the devices to be discussed below. In what follows it is to be understood that each of the new types of amplifier can

usually be constructed with a single amplifying element, several elements, or a travelling-wave structure, the arrangement being determined by the gain-bandwidth product required.

Principle of parametric amplification

The new types of amplifier known collectively as parametric amplifiers or reactance amplifiers all depend on the same basic principle which was first studied in connection with mechanical systems more than 70 years ago. In terms of electrical circuits for the simplest possible case the principle is as follows: If in an oscillatory circuit either the capacitance or the inductance is varied periodically at an appropriate frequency of appropriate phase, electrical oscillations can be maintained in the circuit.

To illustrate this it is convenient to concentrate on variations of capacitance and to suppose that these are brought about mechanically by altering the distance between the plates of a parallel-plate capacitor. If C is the capacitance and Q the charge stored on the capacitor the stored energy is $Q^2/2C$, so that if the capacitance is decreased by pulling the plates further apart the stored energy will increase and work will have been done on the system.



2 *Principle of parametric amplification*

a tuned circuit
b build-up of oscillations
c decay of oscillations
d variable capacitance as amplifier
e variable capacitance coupling two oscillatory circuits
f up-convertor
g down-convertor

The additional energy results from the fact that in a charged capacitor the plates attract each other and work is done when they are pulled apart. On the other hand there is no change in the energy of the system if the separation of the plates is changed when the capacitor is uncharged.

Referring to Fig. 2, suppose an oscillatory current to be flowing in the tuned circuit **a** and let the capacitance C be decreased discontinuously whenever the charge on the plates is a maximum and increased discontinuously to its former value whenever the charge is zero. Each decrease will add energy to the circuit while the increases will leave the energy unchanged.

Thus if the circuit is lossless the amplitude of the oscillatory voltage across the capacitor will build up indefinitely, as shown in Fig. 2b. The mechanical power used to alter the separation of the plates of the capacitor is converted into electrical power in the circuit.

Two further points are worth noting. First, if C had been increased whenever the charge was a maximum and returned to its original value whenever the charge was zero, power would have been abstracted from the circuit and the original oscillation would have decayed as in Fig. 2c. Secondly, the frequency of the capacitance variation is exactly double that of the oscillatory current. Thus frequency and phase relations are of the first importance.

For simplicity we have assumed the capacitance variation to have a square waveform, but it is easy to see that similar results would have been obtained with a sinusoidal variation.

Analogy with a pump

So far the device has been presented in a form which causes the build-up of oscillations in a lossless circuit without the aid of any electrical generator. This clearly represents an oscillator. Suppose however that we have the conditions shown in Fig. 2d where a generator of angular frequency ω and internal resistance R_0 is supplying power to a load resistance R_1. If C is varied with angular frequency 2ω and with appropriate phase, power will be delivered to the circuit, and the oscillatory current of frequency ω flowing through the load will be greater than it would have been in the absence of capacitance variations.

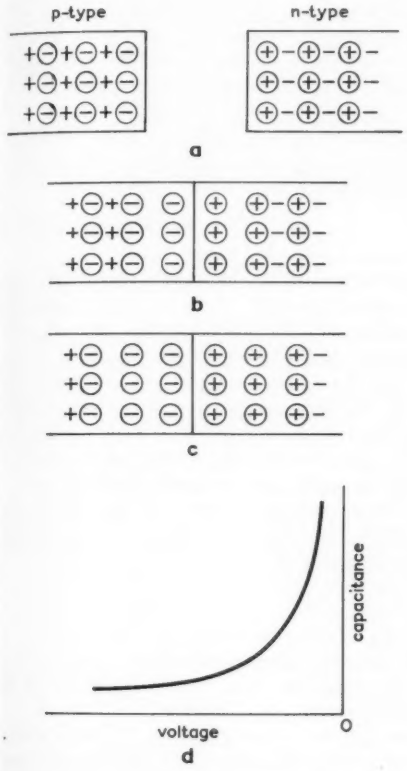
The variable capacitance is now acting as an amplifier with a gain depending on the magnitude of the capacitance changes. If these are large enough the power supplied may exceed that dissipated by R_0 and R_1. The circuit then becomes unstable and the electrical oscillations increase in amplitude without limit.

There is an obvious analogy between the action of the variable capacitance in this circuit and the action of a pump. In fact the variable-reactance element in a parametric amplifier is usually known as the pump and its frequency of variation as the pumping frequency.

In general the signal to be amplified will contain a finite band of frequencies, so we consider next what will happen to a signal component of angular frequency

$\omega + \delta\omega$ (where $\delta\omega \ll \omega$) when the pump frequency is 2ω. In these circumstances the phase of the signal relative to that of the pump will pass through all values between 0 and 2π.

At some parts of the phase cycle the signal is amplified while at others it is attenuated, and the amplitude of the current through the load resistance rises and falls although



3 *p–n junctions as variable-reactance elements*

⊕ immobilized ionized donor
⊖ immobilized ionized acceptor
\+ mobile positive hole
− mobile electron
a *p*- and *n*-type materials
b *p–n* junction without bias
c *p–n* junction with reverse bias
d typical capacitance/bias curve

there is no corresponding variation in the amplitude of the component of frequency $\omega + \delta\omega$ in the input signal. This variation in the load current makes the amplifier of little practical use.

Currents of other frequencies

It is instructive to consider this result from a different point of view. We may suppose that as a result of the non-linearity of the circuit there will be present in it not only currents of the signal and the pump frequencies but also sum-and-difference frequency currents, harmonics, etc.

Of the various possible combinations, only those are important whose frequencies are approximately equal to the resonant frequency of the circuit. These are the signal frequency and the difference between the signal and pump frequencies, and both of these are amplified. When the pump frequency is exactly twice that of the signal the two amplified components have the same frequency (that of the signal) and will add vectorially. Thus the over-all result will be amplification or the reverse depending on the relative phases of the signal and the pump.

On the other hand if the pump frequency is 2ω and that of the signal $\omega + \delta\omega$ the two amplified components of load current will have frequencies $\omega + \delta\omega$ and $\omega - \delta\omega$ respectively. They will therefore beat with each other and cause the fluctuations in load current already remarked.

At first sight it looks as though we could overcome this difficulty if we could remove the $\omega - \delta\omega$ component. This however is not the case, for more detailed consideration shows that it is the combination of this component with the pump frequency 2ω that produces amplification at $\omega + \delta\omega$. Both $\omega + \delta\omega$ and $\omega - \delta\omega$ are necessary but they must somehow be separated. This is difficult when they are nearly equal, so we are led to consider the arrangement shown in Fig. 2e.

Idling circuit

Here we have two oscillatory circuits coupled by the varying capacitance C. In circuit 1 is an input signal represented by the generator E, and a load resistance R_1. R_0 represents the internal resistance of the generator and any other losses in the circuit. This circuit is tuned to the angular frequency ω_1 of the generator. Circuit 2 whose losses are represented by R_2 is tuned to some other frequency ω_2 which is very different from ω_1. This is often termed the idling circuit. The pumping frequency ω_3 is given by:

$$\omega_3 = \omega_1 + \omega_2$$

Analysis of this arrangement shows that the results are very similar to those previously obtained with the arrangement of Fig. 2d. The pump feeds power into circuits 1 and 2 at the frequencies to which these circuits are tuned, and, if the pump amplitude is great enough, oscillation will occur at both of these frequencies. For smaller pump amplitudes circuit 1 acts as an amplifier since the current flowing from E through R_1 is greater than it would have been in the absence of the pump.

However by the provision of the idling circuit and by making ω_2 very different from ω_1 we have achieved the required separation of the currents of these two frequencies. Thus the strict frequency and phase relations which had to be satisfied in the simple circuit of Fig. 2a are no longer necessary. In consequence amplification in circuit 1 can be obtained over a finite band of frequencies

and the whole device forms the basis for a practical receiver of modulated signals.

One difference between the parametric amplifier just described and more conventional amplifiers should be noted. In a conventional amplifier d.c. power is converted into power at the signal frequency. In the parametric amplifier on the other hand power comes from the pump which represents a source of alternating supply.

Parametric frequency-changers

In conventional receivers we are familiar with frequency-changers consisting essentially of non-linear resistors. With such devices the change from the signal to the intermediate frequency is always accompanied by a loss of power.

In view of what has already been said about parametric amplifiers it is not surprising that parametric frequency-convertors can be constructed in which the conversion is accompanied by a power gain. One way is to modify the circuit of Fig. 2e so that the load resistance R_1 is connected in circuit 2 instead of in circuit 1.

In this type of frequency changer, as in the amplifier described previously, the pump frequency ω_3 is the sum of the signal frequency ω_1 and the output (or idler) frequency ω_2. It is possible however to construct a frequency changer in which $\omega_3 = \omega_1 - \omega_2$, and there is an important difference between the two arrangements.

When $\omega_3 = \omega_1 + \omega_2$ the gain of the device can be made as large as we please by supplying sufficient power from the pump. Ultimately when the pump power is large enough the circuit will become unstable. On the other hand when $\omega_3 = \omega_1 - \omega_2$ the circuit is inherently stable, and it can be shown quite generally that the ratio of the output power at frequency ω_2 to the input at ω_1 cannot exceed ω_2/ω_1. We therefore have the two arrangements shown in Figs. 2f and 2g, which are referred to as an up-convertor and a down-convertor respectively.

There are still other possibilities which cannot be discussed here, but it should be mentioned that there are circuit arrangements with which amplification or conversion gain can be achieved even though the pump frequency is lower that that of the input signal. This may become important at extremely high frequencies where the provision of adequate pump power at still higher frequencies would be difficult.

Variable-reactance elements

The above description of the principles underlying parametric amplification has assumed the use of a capacitor whose value can be varied periodically by mechanical means, but it is obviously much more convenient to vary the capacitance electrically. Furthermore the theory could have been stated equally well in terms of a time-varying inductance rather than a time-varying capacitance. We now consider how such time-varying reactances can be realized in practice.

The first device is the microwave analogue of a saturable reactor. Since we wish it to operate at microwave frequencies we choose a ferrite as the material whose effective permeability is to be varied. We apply to it a steady magnetic field of such strength that ferrimagnetic resonance occurs when the material is placed in a suitable cavity and supplied with power at the pump frequency from a local oscillator. In these conditions the ferrite can act as a non-linear reactor.

There are various ways in which effective resonant circuits can be arranged for the signal and idler frequencies but details of these are not given because at present ferrite amplifiers appear to be less useful than some other types. Even with the most satisfactory material so far used, yttrium–iron garnet, the pumping power required is large and the gain-bandwidth product rather small. It is not impossible that this situation might be changed by the discovery of materials with better properties.

p–n junctions

A much more promising device makes use of the properties of *p–n* junctions (Fig. 3a) in semiconductors, particularly in silicon. At such a junction, in the absence of any bias, holes from the *p*-type material diffuse across the boundary into the *n*-type material and combine with electrons there. Similarly electrons from the *n*-type material diffuse into the *p*-type region and there combine with holes. The over-all result is to leave unneutralized acceptors in the *p*-region and unneutralized donors in the *n*-region. These constitute a space charge which sets up a potential difference between the two regions and opposes further diffusion.

In equilibrium conditions very little diffusion occurs and the situation is as represented in Fig. 3b, where we have two regions of high conductivity separated by a depletion layer, near the junction, in which there are very few free holes or electrons. This layer is therefore one of very low conductivity.

Suppose now that we apply across the junction a bias in the reverse direction. This will cause the flow of some steady reverse current, but in a suitable diode this current is very small and may be ignored. In addition the bias increases the p.d. between the two sides of the junction and this increase must be balanced by an increase in the space charge in the depletion layer as shown in Fig. 3c.

To bring about this change, there is a transient flow of holes and electrons round the battery circuit. Whenever the bias voltage changes there is a corresponding flow of charge in the battery circuit, so the *p–n* junction acts as a capacitor. More detailed investigation shows that the effective capacitance for small signals is a function of the bias voltage and may vary by a factor of 5 or more over the range of reverse-bias voltages that can be applied in practice. A typical variation of capacitance with bias is shown in Fig. 3d.

Electron beams

The third device to be considered is one in which an electron beam is used to produce a variable reactance. A possible arrangement is shown in Fig. 4. This is not the

device which at present is giving the most promising results but it does illustrate the general principle in a particularly simple manner.

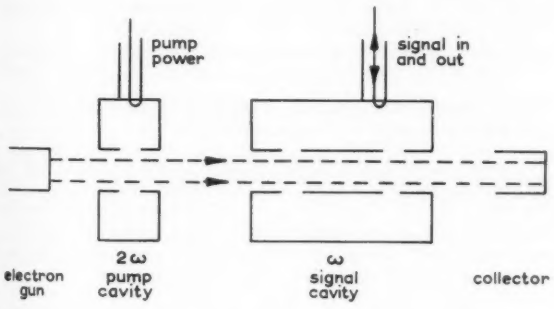
The signal cavity is coupled to the electron beam at two gaps and the distance between these gaps controls the effective impedance which the beam adds to the cavity. In particular if the distance corresponds to an electron drift angle of $(2n + 1)\pi$ the impedance is purely inductive. Furthermore the impedance can be varied at the pump frequency by means of the second cavity shown in the Figure.

The device can therefore function as a regenerative parametric amplifier of the simplest type. It is not difficult to see that other arrangements involving idling circuits or a travelling-wave structure are possible.

Some comparisons

Parametric amplifiers have been made to operate with each of the variable-reactance devices discussed earlier. Furthermore with most of the basic types of amplifier it is possible to use single circuits, multiple circuits or travelling-wave structures. Thus the total number of possibilities is already very large and is continually growing. A detailed comparison of the results so far achieved with the different types would be unrewarding, and only general comments are made.

Experiments with these amplifiers have been carried out at various frequencies up to about 10 Gc/s and a given amplifier can usually be tuned over a frequency range of the order of 5%. The bandwidth at any particular mean



4 *Electron beam to produce variable reactance*

frequency is of course greater with travelling-wave structures than when single cavities are used. It seems unlikely that there will be much difficulty in achieving adequate bandwidth for all ordinary applications.

Maximum frequency of operation

It is perhaps rash to speculate about the maximum frequencies at which the various types of amplifier are likely to be useful. However it is not unreasonable to expect that any attempt to operate electron-beam parametric amplifiers at the highest frequencies will encounter the same difficulties as are met in more conventional tubes: cathode loading, dissipation of heat, fabrication of the electrode structure, etc. Perhaps it should be possible to use them at frequencies up to 10 Gc/s although at present good results have been reported only at 500 Mc/s.

With diode parametric amplifiers the problem is to construct diodes of very small capacitance and therefore very small size without at the same time increasing their series resistance unduly. Satisfactory operation at 6 Gc/s has been reported and there is no reason to doubt that this limit can be raised very considerably.

As mentioned above parametric amplifiers using ferrites for their variable-reactance elements are not yet particularly attractive for frequencies up to 10 Gc/s. They may however come into their own at still higher frequencies where the other types are likely to run into increasing difficulties. While it is possible to envisage methods of constructing ferrite amplifiers for the millimetre-wave region little progress in this direction has yet been made.

For the diode and electron-beam types of parametric amplifier, pumping powers of the order of 10 mW are generally adequate. Ferrite amplifiers usually require much larger powers.

Noise factor of electron-beam parametric amplifiers

Turning to the all-important question of noise factor it is convenient first to compare electron-beam parametric amplifiers with conventional electron-beam tubes. Noise in the latter arises from fluctuations in the electron stream, and these fluctuations are relatively large because the electrons have come from a hot cathode. For such tubes there are some quite fundamental theorems which set a limit to what can be done to reduce noise.

The theorems do not apply to electron-beam parametric amplifiers and so there is no fundamental reason why these should not have much lower noise factors than conventional travelling-wave tubes, backward-wave amplifiers and the like. However the parametric amplifiers still operate with a beam of electrons in which the usual fluctuations are present, and low noise factors will be obtained only if there is some mechanism whereby noise induced by the beam is cancelled.

With the arrangement discussed previously (Fig. 4) it is easy to see how this may come about. Noise induced in the pump cavity is of no importance since it is negligible in comparison with the pump power. This is certainly not true of the signal cavity but here we have noise voltages induced at each of the two gaps. In the conditions previously discussed where the drift angle between the gaps is $(2n + 1)\pi$ these voltages should cancel.

In practice cancellation is never complete and how far it is achieved depends on the detailed motion of the electrons between the gaps. With this particular arrangement of electrodes useful cancellation has not yet been obtained, though good noise factors have been reported with a rather different type of electron-beam parametric amplifier.

At present it is perhaps unsafe to generalize about

these new amplifiers. All we can say is that in principle noise cancellation is possible and has been demonstrated to a useful extent at 500 Mc/s. Results at higher frequencies remain to be seen.

Noise factor of diode parametric amplifiers

The diode parametric amplifier has a large initial advantage over the electron-beam type in that all parts of the diode are at room temperature and fluctuations in any electron currents which flow are therefore much smaller than they would be if the electrons came from a hot cathode.

In addition the diode behaves as a capacitor and not as a resistor and we might therefore expect that it would inject no noise into any circuit to which it was connected. In practice the diode inevitably has some resistance as well as reactance, and the resistance is a source of noise. The indications are however that it will be possible to build diode amplifiers with very low noise factors.

How far is it worth while to carry the reduction of noise in a microwave amplifier? Clearly there is little to be gained by going further when the noise introduced by the amplifier is already small in comparison with the noise accompanying the signal received from the aerial. Much depends therefore on the aerial, and the extreme case occurs in radio astronomy, when a highly directive aerial is pointed away from the earth. Then the best possible amplifier may be justified, and it is for work of this kind that masers are being used since they introduce virtually no additional noise.

With aerials other than those used in radio astronomy the directivity is usually not so great and some of the side-lobes often impinge on the surface of the earth even when the main beam does not. Noise radiated from the earth is added to the signal and it seems likely that parametric amplifiers will then leave little to be desired. They should be cheaper and simpler to operate.

Summary

A new class of microwave amplifiers has recently been studied in which the active element is a reactor whose value is made to vary at the frequency of a local oscillator usually known as the pump. With suitable circuits, amplification at the frequency of an input signal may be obtained. Alternatively the amplified output signal may be shifted in frequency to a value which is simply related to the frequencies of the input signal and the pump respectively.

The active element may consist of an electron stream coupled to a suitable electrode structure, a back-biased junction diode or a ferrite contained in a suitable resonator. In each case the resulting amplifier may be expected to have a very low noise factor and this expectation is confirmed by the results so far obtained.

Symposium on data-handling and display systems for air traffic control

THE steady increase in air traffic and its speed of movement impose heavy responsibility upon air traffic control organizations. This is particularly critical near the terminals of the main air routes during times of poor visibility, when the arrival rates of aircraft may exceed the landing rates determined by the prevailing weather conditions. The safety measures necessitated at these times can lead to expensive and inconvenient delays as aircraft await their turn to land.

It is logical to expect that the efficiency of air traffic control will be improved when the controllers can be freed from the purely routine matters of aircraft movements. It is in this function that automatic systems of data and information handling can play a vital part and thereby increase the volume, efficiency and safety of aircraft movements.

The Electronics and Communications Section is holding a Symposium on data-handling and display systems for air traffic control. This will take place during afternoon and evening sessions at Savoy Place on Friday, 8th April 1960, when a number of papers (summarized below) will be read and discussed. The afternoon (2.30 p.m.) session will deal with flight-information processing and the evening (5.30 p.m.) session with radar data handling.

Survey of data handling for air traffic control (*3241*) by J. C. Farmer, B.SC., and M. F. Whitney, B.SC.

CURRENT methods of air traffic control are outlined, and relevant techniques discussed in other papers are examined.

An electronic computing system for air traffic control (*3240*) by C. G. H. Scholten

A DUTCH system known as Satco is described.

An automatic radio triangulation system (*3243*) by R. F. Cleaver, M.SC.(ENG.), P. Sothcott, B.SC., and Group-Capt. F. J. Robinson, O.B.E., D.F.C., R.A.F.

AUTOMATIC position-finding is carried out by using the signals radiated in the course of ordinary communication with the ground.

Contribution on **Experimental electronic data-processing system for air traffic control** by J. S. Macmullan, B.SC.

An experimental system for automatic radar target detection and digital coded plot extraction and transmission (*3248*) by G. L. F. Hinckley

THE system provides means for automatic detection, automatic extraction and automatic digital encoding of radar plot data available from two-dimensional search radars.

Semi-automatic flight control using extracted radar data (*3247*) by C. C. Fielding, B.SC., and J. G. Gibbs, B.SC.

DETAILED control of aircraft from take-off to a fixed or moving point in space and over a given area is discussed.

A cathode-ray-labelled plan display (*3246*) by N. J. Smith, M.A., and P. F. Heggs

A MAGNETICALLY deflected cathode-ray tube is used to display, in Cartesian form, the relative positions of aircraft, each position being labelled by numbers etc. and a vector.

Methods of extracting radar data for automatic processing (*3244*) by N. J. Smith, M.A., and B. W. Oakley, M.A.

THE AUTHORS consider the conversion of radar data into a form suitable for digital computers.

Fixed-coil display system for data extraction (*3245*) by W. F. Ashton

THE system is designed to assist accurate extraction of data by manual methods.

An electrical engineering review

Printed-wiring techniques

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Printed wiring, introduced during the Second World War, forms the basis of automatic component-assembly techniques. In this article Mr. Dummer (who is at the Royal Radar Establishment) briefly describes the materials and methods used to produce the wiring, including the etched-foil process, and reviews the technical and economic advantages of the various systems of component insertion. He examines the reliability of printed wiring, the work being done to secure satisfactory operation at high temperatures, and the possibility of microminiaturization by evaporation techniques.

G. W. A. DUMMER, M.B.E., MEMBER

ALTHOUGH the first printed-wiring system was patented in England in 1892 it was not until the end of World War II that commercial development became possible, mainly because until then suitable base materials had not been available for etched-foil techniques. The economic advantages, particularly the saving achieved by dip soldering, were realized about this time, and the increasing use of radio and television receivers encouraged considerable development of printed-wiring and dip-soldering techniques. This extended to computers, test instruments, industrial electronic equipment, radar and guided missiles, and printed wiring now forms a large part of the industrial electronics production of the United Kingdom.

Mass production of transistors has greatly influenced printed wiring, since the lower operating voltages and lower impedances minimized the problems of surface insulation etc. present in valve circuits, and transistorized printed-wiring assemblies of all kinds are now widely used.

Before the almost universal use of the etched-foil technique today many systems were tried with varying degrees of success. These included painting and firing conducting lines on ceramic and glass bases, metal spraying and milling processes on plastic bases, silver-ink printing methods, die-stamping and embossing and metal spraying through stencils.

Few of these techniques are now employed except perhaps for special applications. They were mostly printed-*wiring* systems in which the wiring only was deposited and components were attached separately, whereas printed *circuits* now denote wiring with the addition of deposited components such as resistors, inductors, capacitors, etc.

Base materials

The requirements for a suitable base material for any printed-wiring system are:

(1) good electrical insulation (over the required range of climatic conditions)
(2) satisfactory mechanical strength (over the required range of temperature)
(3) ease of fabrication (cutting, punching, etc.)
(4) availability at reasonable cost.

In practice, (1) and (2) are often compromises but for many years synthetic-resin-bonded-paper laminate boards have been used in quantity. Copper foil is readily bonded to this material; the boards are reasonably cheap, easily punched and machined and their electrical and mechanical properties are adequate for the majority of commercial uses. On the other hand their resistance to tracking is not good and their mechanical properties are inadequate for some arduous Services requirements.

Glass-fibre laminates

Glass-fibre laminates impregnated with epoxy resin have superior mechanical properties over a wider temperature range and also retain their electrical characteristics in high humidities up to temperatures of 150°C. The material is difficult to process however and its cost is several times that of the phenolic paper laminates. Copper bonds readily to it and it has the highest bond strength of any base material to date.

Glass fibre impregnated with silicone resin possesses excellent electrical properties—low loss, high insulation resistance, etc.—but these are not maintained in conditions of high humidity. The material is mechanically weak with a tendency to delaminate. It is difficult to bond copper to its surface and (as epoxy resin is often used) the upper operating temperature of the board is limited to that of the adhesive.

Glass-fibre laminates impregnated with polytetrafluorethylene resin have the best electrical characteristics of materials to date, i.e. low loss, high insulation resistance, excellent resistance to tracking, etc., all of which are retained up to approximately 250°C. The material is mechanically stable and readily fabricated. Special treatment of both the copper and the p.t.f.e. is essential to obtain a satisfactory bond.

Recent developments in the treatment of p.t.f.e. have made it possible to bond copper to it to produce unreinforced sheets which provide an ideal base for high-quality printed wiring. Materials of this class are the

Table 1. Characteristics of some base materials

type of material	relevant British Standard	power factor at 1 Mc/s (maximum)	permittivity at 1 Mc/s (maximum)	insulation resistance after water immersion (minimum)	water absorption (maximum)	cross breaking-strength (minimum)	maximum operating temperature	characteristics and suggested uses
				megohms	mg	lb/in.^{2}	deg C	
phenolic/paper laminate (s.r.b.p.)—type H	2076	0·038	5·0	5×10^4	13	10000	100	good-quality electronic units with stable electrical properties
phenolic/paper laminate (s.r.b.p.)—type L	2076	0·045	5·8	500	32	12000	100	lower-quality electronic units
phenolic/fabric laminate (s.r.b.p.)—electrical grade	972 1137	0·045	5·8	500	50	12000	100	units where mechanical strength is important
acetylated cotton—type P	972 1137	0·01	2·9	10^5	75	10000	60	very stable electrically; for use in conditions of high humidity
phenolic/glass-fibre mat		0·035	4·4	100	30	35000	120	mechanically and thermally stable
epoxy/glass-fibre laminate*		0·035	4·7	10^3	4	70000	150	mechanically and thermally stable, low water absorption
polyester/glass-fibre laminate		0·02	3·7	0·5	4	15000	120	as above
silicone/glass-fibre laminate—type S1*		0·005	3·7	10^4	10	14000	200	good insulation resistance when wet; low loss when dry
p.t.f.e./glass-fibre laminate*		0·001	2·85	$> 10^6$	very low	12000	250	excellent electrical properties (low loss and permittivity): stable and satisfactory at microwave frequencies

The properties quoted are for typical plastic material without copper-clad surfaces. The starred materials are in the development stage and a specification is being drawn up to cover them. Some values may differ widely from those given above. In general, commercial plastic materials are well within the limits: e.g. B.S. 2076 gives the minimum insulation resistance after 24h immersion in water as 500 megohms (type L material); manufacturers' minimum is 2000 megohms

only ones suitable for use at very high frequencies, i.e. up to microwave frequencies. Their only disadvantage is their high cost. Improvements in polystyrene and its co-polymers are resulting in copper-clad low-loss materials which cost less than p.t.f.e. although of course they operate at lower temperatures.

The characteristics of some base materials in present use, together with some future developments, are given in Table 1.

Circuit lay-outs

The circuit to be printed is first drawn roughly in a 2-dimensional form and the sketch transferred to a transparent plastic sheet of high dimensional stability on which is already printed a standard 0·1in. grid pattern usually scaled up four times (i.e. 0·4in. spacing). Cut-outs four times the size of components are placed in position to achieve suitable spacing. Final minimum line widths of 0·03in. with a minimum spacing of 0·05in. between lines are desirable.

When the components and wiring are satisfactorily arranged the lines are drawn in with opaque ink or paint (still four times larger). Suitable registration and identification of components can be added to this master drawing at this stage. It is usual to round off the corners of the wiring, and some examples of techniques used in laying out wiring lines and terminations are shown in Fig. 1.

The master drawing is now photographed with a 4 : 1 reduction to provide a high-contrast negative to be used in the printing process.

Silk-screen printing

There are available several methods of printing the pattern onto the base (shown diagrammatically in Fig. 2), one common process being silk-screen printing.

From the master drawing a positive is made. A plastic film coated with a sensitized emulsion is contact-printed by normal methods. This, when developed, allows the required pattern outline to be completely removed. The plastic film with its emulsion is pressed onto the silk or wire screen, thus filling that part of the mesh not required for the wiring pattern. The plastic backing film is then stripped off.

A viscous ink is applied by squeegee to the copper board through the mesh to form an acid-resisting wiring pattern on the copper, which is subsequently etched in the normal way.

Lithographic off-set printing and photographic processes

A lithographic plate as used in normal off-set name-plate printing can be used to carry the required wiring pattern prepared from the negative. This is printed onto the copper-clad laminate, but the film is too thin for

acid resisting, and reinforcement by dusting with bitumen, with subsequent heating, is necessary. The etching process follows as before.

A photographic process provides the best definition of all, and as it is suitable for large- and small-quantity production it is described more fully in the following account of the etched-foil system of producing printed wiring.

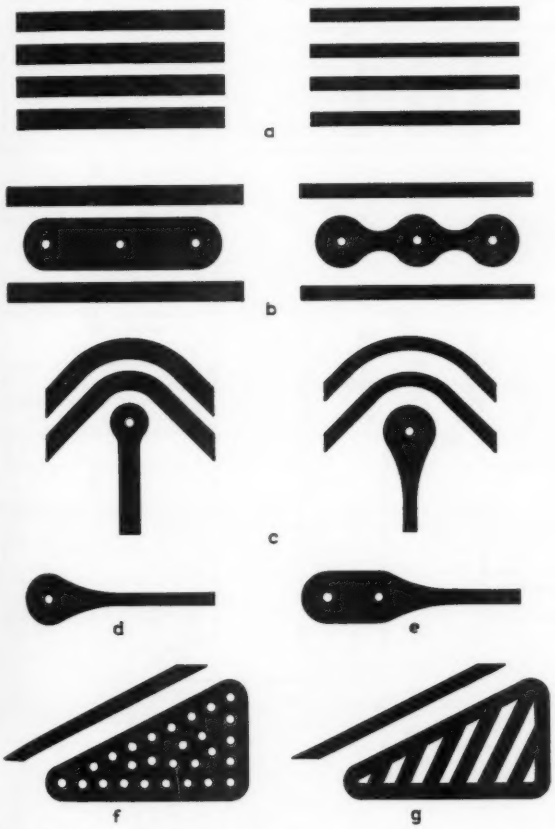
The etched-foil system of printed wiring

Base materials for the etched-foil system must have copper bonded to one or both sides of the board. Very pure (electrolytically produced) copper foil is available in continuous sheets in considerable widths: two weights commonly used are 1oz/ft² (nominally 0·00135in. thick) and 2oz/ft² (0·0027in. thick). A thin foil, when processed to form wiring lines, can carry surprisingly high currents compared with conventional solid circular wires. For example a line 0·03in. wide and 0·00135in. thick will carry 3amp with a rise of 40°C above the ambient temperature.

In the photographic process of printing, the selected copper-clad material is coated with a photosensitive emulsion (a bichromated colloid or a proprietary solution). This can be applied by spraying, dipping or whirling and is dried slowly. The negative, prepared as previously described, is placed in contact with this surface and exposed to ultraviolet light for about one minute to harden the emulsion through the clear circuit-pattern lines.

Development in suitable solvents dissolves the unwanted emulsion, leaving the required circuit pattern in the form of an acid-resist on the copper surface. The remaining unwanted copper is then etched away in an acid bath—usually ferric chloride. Thorough washing and drying complete the printing process. These stages are shown diagrammatically in Fig. 3.

The required holes are punched and the board is cropped to shape where multiple wiring patterns are used. It is then ready for the insertion of the components, soldering, etc. Fig. 4 shows some boards produced by the etched-foil technique.



1 *Examples of wiring lay-out*

a, b, c show methods of increasing line spacing at the expense of line width
d, e show typical terminations
f, g show breakdown of copper areas

The plated-up process

An alternative method of producing printed wiring is by electrodepositing the required copper-wiring pattern onto the base. The board is punched and cropped to size first and (usually by silk-screening) the unwanted pattern is printed on the surface in ink. The entire surface is then sprayed with a silver paint which adheres only to the unprinted part of the board. Electrodeposited copper or silver is then plated-up on the required pattern to the desired thickness. The unwanted pattern, having no adhesion, can be removed.

In this system, deposition occurs through the holes and over the edge of the board, providing mechanical keying without which the wiring adhesion might be poor. After the unwanted pattern is cleaned off, the board is ready for component insertion.

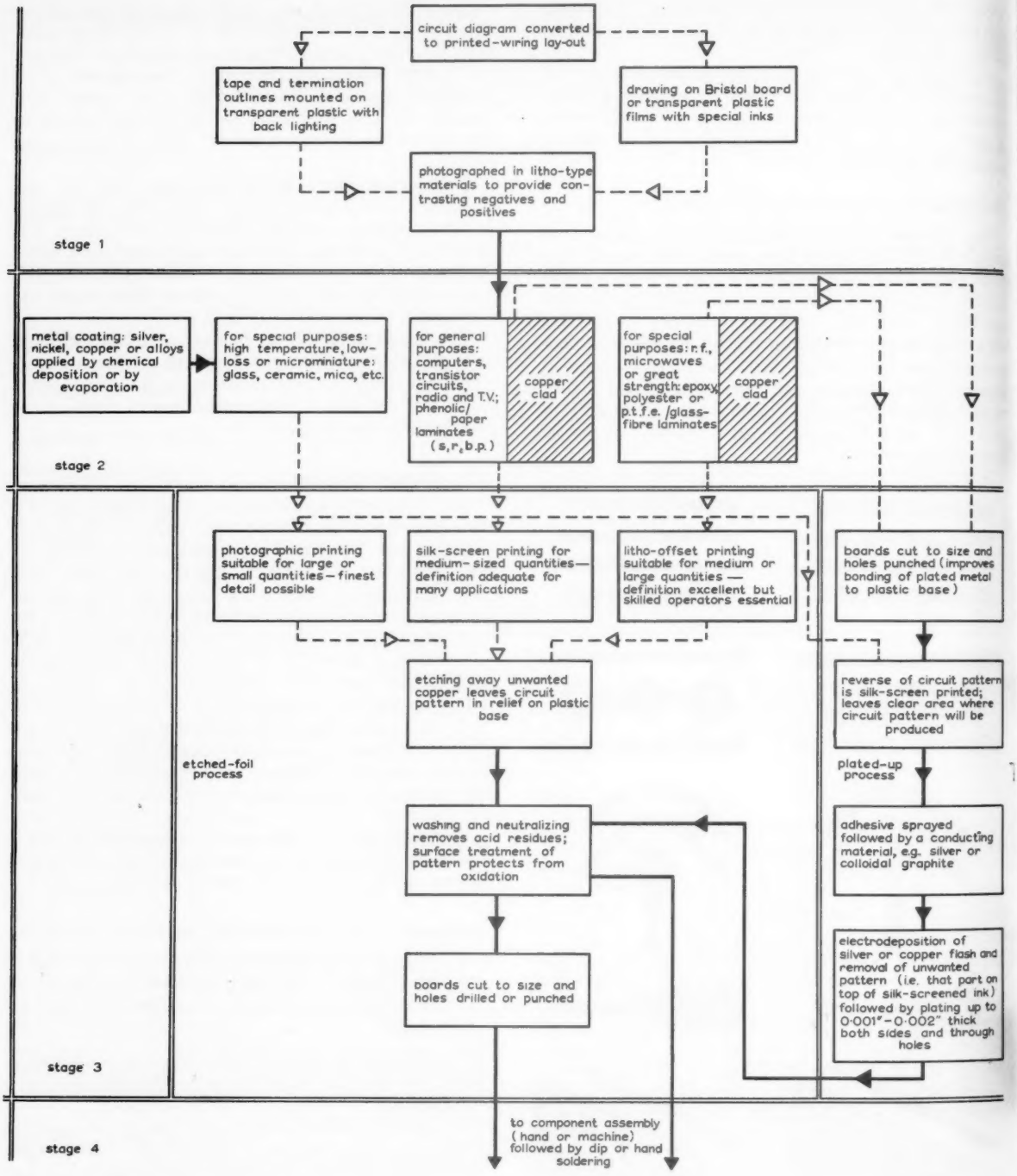
Both the above processes can be mechanized. Fig. 5 shows a machine for the automatic manufacture of printed-wiring panels by the etched-foil process.

Automatic component-insertion machines

Considerable experience has been acquired, mainly in the United States, in the design and use of machines for automatic insertion of components. These fall into two main classes:

(a) The 'in-line' or single-component insertion machine in which the board moves along under different heads, each of which inserts one type of component, and
(b) A machine in which the board is moved into position under a single-insertion head through which various components are fed. It is usually controlled by punched cards.

The limitation of both systems is that they will insert components only of tubular shape and limited size, although special heads can be designed to insert odd-shaped components (transformers, valveholders, etc.).

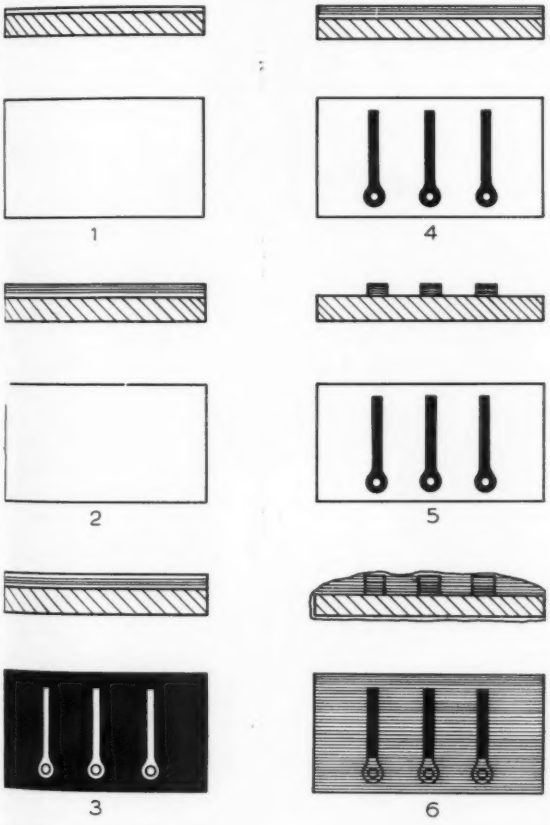

circuit diagram converted to printed-wiring lay-out
tape and termination outlines mounted on transparent plastic with back lighting
drawing on Bristol board or transparent plastic films with special inks
photographed in litho-type materials to provide contrasting negatives and positives
stage 1
metal coating: silver, nickel, copper or alloys applied by chemical deposition or by evaporation
for special purposes: high temperature, low-loss or microminiature: glass, ceramic, mica, etc.
for general purposes: computers, transistor circuits, radio and T.V.; phenolic/paper laminates (s,r,e b.p.)
copper clad
for special purposes: r.f., microwaves or great strength: epoxy, polyester or p.t.f.e. /glass-fibre laminates
copper clad
stage 2
photographic printing suitable for large or small quantities—finest detail possible
silk-screen printing for medium-sized quantities—definition adequate for many applications
litho-offset printing suitable for medium or large quantities — definition excellent but skilled operators essential
boards cut to size and holes punched (improves bonding of plated metal to plastic base)
etching away unwanted copper leaves circuit pattern in relief on plastic base
reverse of circuit pattern is silk-screen printed; leaves clear area where circuit pattern will be produced
etched-foil process
plated-up process
washing and neutralizing removes acid residues; surface treatment of pattern protects from oxidation
adhesive sprayed followed by a conducting material, e.g. silver or colloidal graphite
boards cut to size and holes drilled or punched
electrodeposition of silver or copper flash and removal of unwanted pattern (i.e. that part on top of silk-screened ink) followed by plating up to 0·001"–0·002" thick both sides and through holes
stage 3
to component assembly (hand or machine) followed by dip or hand soldering
stage 4

2 *Stages in the manufacture of printed wiring*

Stage 1: lay-out of circuit pattern and photography for production of master pattern, negatives and positives
Stage 2: choice of base material for various applications
Stage 3: processes to produce circuit pattern on base material
Stage 4: component assembly

In the United Kingdom semi-automatic methods of component insertion are being used which allow reasonable flexibility without the large capital cost of fully automatic machines. The general impression is that, unless very-large-scale production of repetitive circuits is required, machines capable of producing 10000 circuits per day are not necessarily economically advantageous. It seems better to combine manual insertion with simple machines to achieve the necessary flexibility at a reasonable cost.

In some cases single-insertion machines of the in-line type can be used for this purpose; Fig. 6 shows a typical machine where components are inserted by an operator and Fig. 7 depicts a series of such machines with a conveyor belt for high rates of production. The pre-drilled wiring board is first lined up with the insertion head by magnetic stops, the component is inserted and the leads are clenched under the board. The machine also crops and forms the leads before insertion.

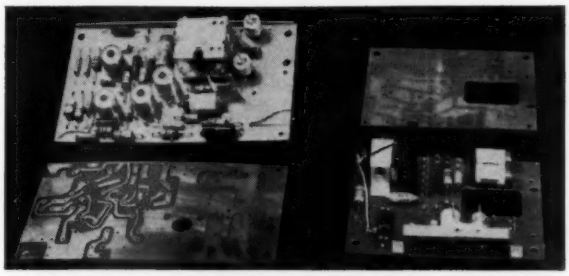


3 *The etched-foil process*

1 copper-clad plastic laminate
2 copper coated with photo-resist
3 resist film exposed to ultraviolet rays through maximum-contrast negative
4 resist film is developed and only the required wiring pattern remains
5 unwanted copper is etched away in ferric chloride
6 terminations are plated and unit is thoroughly washed, dried and suitably protected

Experimental machines

Several experimental machines for automatic and hand-operated insertion of components have been built in the United Kingdom. In one system a board is mounted, wiring side down, over a jig, and the components with their leads formed (but not cropped) are inserted by hand. When all the components are inserted a clamp holds them in position and a blade traverses the underside of the board, cutting off the surplus leads and bending them simultaneously by a wiping action.



4 *Printed circuits with wiring produced by the etched-foil method*

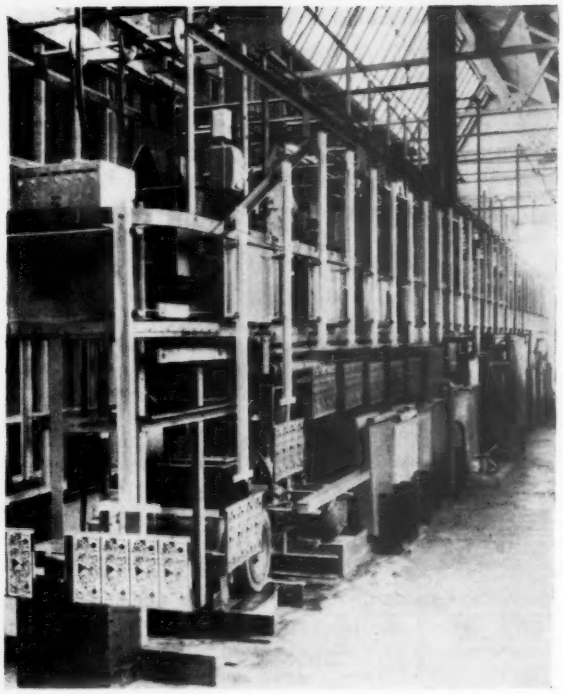
In the United States systems such as 'Tinker Toy' have been explored. In this, starting from raw or semi-processed materials, a series of machines manufacture ceramic base-plates, adhesive carbon-composition resistors and capacitors of plastic, high-permittivity ceramic, etc. The machines also print conducting lines and mount the components so made on the ceramic base-plates. These base-plates, or wafers, approximately $\frac{3}{4}$ in. square by $\frac{1}{16}$ in. thick, are stacked like building blocks to form a module performing one or more electronic functions, the valve being plugged in the top valveholder plate. Automatic inspection machines check physical and electrical characteristics at numerous stations along the line.

Transistorized micromodular systems using wafers 0·31 in. square are currently being explored and are discussed in more detail towards the end of the article.

Special components for printed wiring

The effect on components of the use of component-insertion machines of the in-line type has been to require cylindrical shapes with axial leads and the standardization wherever possible of component-lead diameters. At the same time much attention has been given to the solderability of component leads for subsequent dip soldering, and solder-coated leads are becoming more prevalent. The small component usually has a tubular axial lead, but some larger components such as transformers, electrolytic capacitors, switches, relays, variable capacitors, etc. have been developed with 'snap-in' leads (flat leads) for hand insertion before dip soldering.

For Service equipment, valve mounting often presents a problem. Conventional plug-in valves project at right-



5 *Machine for automatic processing of etched-foil wiring*

angles to the plane of the printed-wiring board and it is difficult to maintain them firmly in shock and vibration conditions and at the same time ensure good heat transfer to a metal chassis. The wire-ended type of valve has some advantages in circuit lay-out as it is possible to use flying leads to cross over the wiring, and also they can be fitted in metal blocks in the plane of the board both to dissipate heat and to withstand shocks.

The increasing use of transistors will minimize these problems.

Automatic soldering

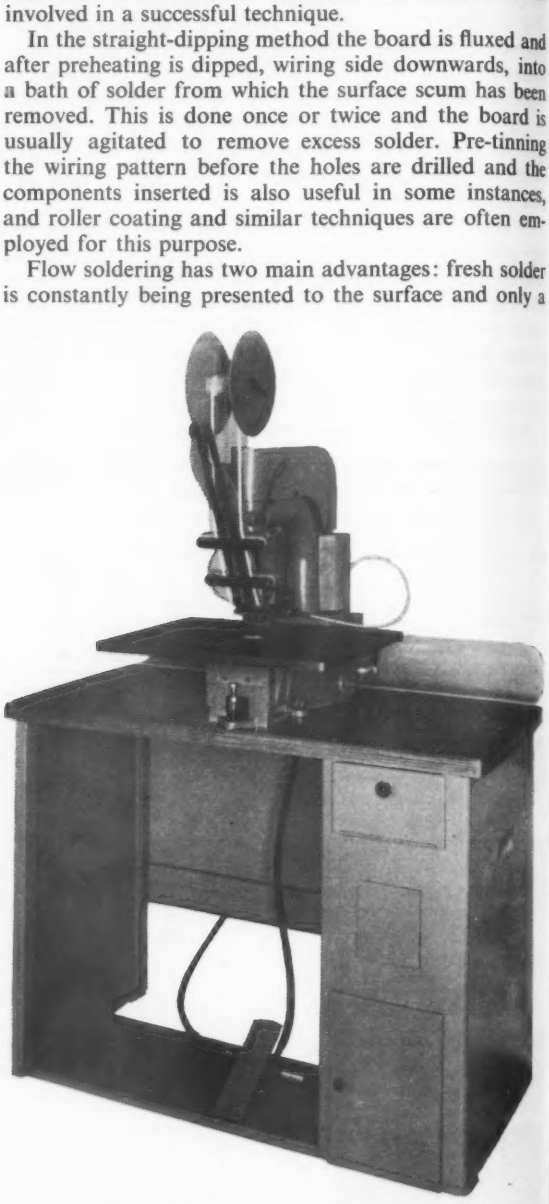
As the wiring pattern is in two dimensions only, soldering of all connections between component leads and the wiring can be carried out in one operation. Many systems of automatic or dip soldering have been evolved. There is little doubt that if the operation is carried out carefully with a well designed system and with chemical cleanliness of both wiring board and component leads complete success can be achieved. However owing to imperfect component leads, bad spots in the copper, lack of cleanliness, etc. hand touching-up of some joints is often carried out.

Many methods of multiple joint soldering exist, ranging from multi-head soldering irons, capillary soldering, raised solder cups, etc. to the straight dipping, pre-tinning and dipping, solder spraying, flow soldering and similar processes.

Most equipment manufacturers have developed processes of their own, and considerable 'know-how' is involved in a successful technique.

In the straight-dipping method the board is fluxed and after preheating is dipped, wiring side downwards, into a bath of solder from which the surface scum has been removed. This is done once or twice and the board is usually agitated to remove excess solder. Pre-tinning the wiring pattern before the holes are drilled and the components inserted is also useful in some instances, and roller coating and similar techniques are often employed for this purpose.

Flow soldering has two main advantages: fresh solder is constantly being presented to the surface and only a small area of the board is heated at any one time. The principle is shown in Fig. 8. Fig. 9 illustrates a flow-soldering machine in which a flared-out rectangular section through which solder is pumped projects a small amount above the level of the solder bath. A 'wave' of solder is pumped from an impeller via a tube so that a



6 *Manually operated component-insertion machine*

continuous motion is obtained and the solder flows evenly over the flare.

The boards to be soldered, after fluxing and preheating, are passed over this wave at approximately 2ft/min and all the connections are rapidly soldered. The bath temperature is controlled at 245° ± 5°C.

Repair of printed wiring

It is important to remember that the 'wiring' consists of copper foil only 1½mils thick, and unless great care is taken any attempt to unsolder component terminations may lead to breaking the copper foil or destroying the bond between the foil and the base material.

This is especially likely if a medium- or high-power soldering iron is used and if, as is common, the wire terminations are bent over onto the wiring. It is therefore recommended that where it is necessary to change a component this is best done by cutting the component terminations on the side opposite to the wiring and soldering the new component to the remaining stub leads.

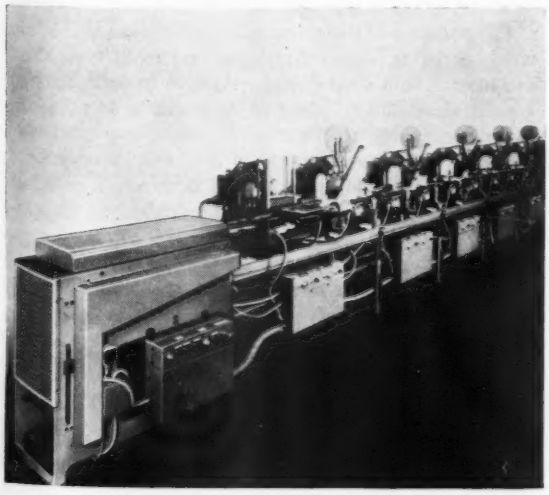
Where clip-in components are used large holes are provided for the terminations, allowing room to bend each individual component back when being unsoldered.

Reliability of printed wiring

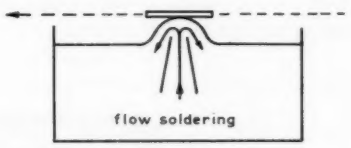
It is difficult to assess the over-all reliability of printed wiring as so much depends on the process used, the care taken in manufacture, cleanliness, and the ultimate environments of the units. In general, if adequate cleanliness is maintained with a well designed processing system, good reliability will be obtained for commercial equipments such as radio and television receivers.

For military purposes, where more arduous conditions are encountered, the reliability may not be so good unless special precautions are taken. Heat/humidity cycling can reveal bad joints not otherwise detectable.

7 *Typical in-line system of automatic component insertion*



The two main causes of unreliability are contamination of boards during processing, which degrades the insulation, and circuit discontinuities (lifting of wiring, open-circuits, dry joints, etc.). Most of the difficulties experienced in military equipment have been due to interconnection problems rather than to actual boards themselves.



8 *Principle of flow soldering*

9 *Flow-soldering machine*

High-temperature printed circuits

Considerable work has been done in the United States on printed circuits for operation at temperatures of the order of 500°C. Layers of conductive and resistive materials have been placed on ceramic plates by either evaporation or chemical-deposition techniques. Up to about 200°C capacitors can be produced experimentally by vacuum deposition of silicon monoxide and similar materials, but although considerable research is being done no satisfactory capacitor can yet be deposited to operate in the 500°C region.

However, circuits of conductive lines (nickel-plated silver), connectors (enamel-bonded leads) and resistors (chromium films etc.) can be made to operate at

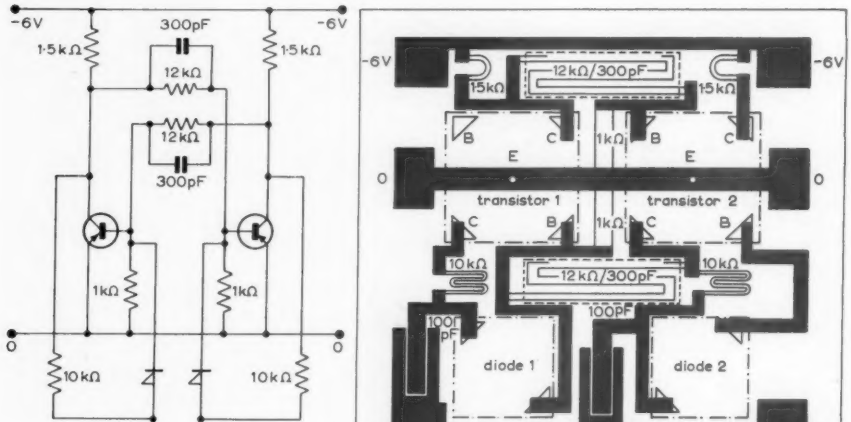
500°C. Geometrical control of these component shapes is achieved by Xero printing the required resist patterns.

Xero printing is an electrostatic printing process in which a dielectric image on a conductive metal base is accurately reproduced by electrical charging and developing with dielectric powders. The technique involves the use of thermoplastic powders which when fused by heat or vapours form chemically resistant barrier-layers.

The techniques are not yet widely used in this country because of limited power-handling capacity, materials and termination problems, etc., and the full advantages have not been realized.

Future developments—microminiature circuits

The limit of packing subminiature components and transistors on miniature printed-wiring boards appears to have been reached, and small boards are now being made for military purposes in which the size has been reduced to a practical minimum. It is possible that present experimental work on evaporated circuits may be the next stage in development. Methods of evaporating metal lines through suitable masks on glass substrates have already been evolved, and the technique of evaporating nickel–chromium and similar materials as fixed resistors has also been employed.



a b

10 *A flat-film binary counter*
a Circuit diagram
b Lay-out
conductive film
resistive film
edge of capacitive top film (separated by dielectric film)
transistor and diode borderlines
Actual size 0·6in. square

Evaporation of dielectric materials is possible and much work is being done. Magnetic materials can also be evaporated in a strong magnetic field to form thin films. Hence conductive, resistive, capacitive and inductive film components can be experimentally made.

Using the active element of a transistor only, i.e. the dice itself, microminiaturization becomes a possibility, and it has been estimated that a reduction in size of approximately ten times is feasible over the most modern subminiature printed-wiring assembly. Fig. 10 shows the circuit lay-out of a binary counter using this technique.

Accurate and careful process control is vital in producing evaporated components, and the reliability (once the development and production phases are passed) should be higher than with conventional types.

Although much remains to be done it seems that printed circuits of this type will eventually be produced

Base-plates of special glass can also be used for 400°–500°C operation and a technique has been developed in which multiple holes can be acid-etched with great accuracy through the glass plate.

Recent work in the United States on silicon carbide transistors shows promise of operation at 500°C; it may therefore be possible to form complete transistor circuits capable of operating at this temperature although it must be emphasized that much experimental work has yet to be done.

Printed circuits for microwave frequencies

It is possible to use printed-circuit techniques in substituting for some waveguides or coaxial lines by printing a top and bottom conductor in a variety of configurations on a low-loss material. Microwave components such as hybrid rings, filters, directional feeds, etc. can be obtained. The base materials used are normally glass-fibre laminates impregnated with p.t.f.e. As this has a permittivity of 2·7 considerable saving of space can result over the normal metal-fabricated waveguides.

The design of printed microwave circuits has been dealt with in great detail by Dukes.*

* DUKES, J. M. C.: 'Application of printed-circuit techniques to the design of microwave components', *Proceedings I.E.E.*, Paper 2401R, August 1959 (105 B, p. 155)

as non-repairable circuits so small that complete circuits may occupy only 0·5in. square or less, on a plate 0·05in. thick.

Acknowledgments

Acknowledgments are made to Mr. H. G. Manfield for assistance in the preparation of this article and to those firms who have supplied illustrations.

Summary

Printed wiring was first introduced during World War II. The various processes developed for its production are briefly described. (Printed wiring is distinguished from printed circuits where components are deposited as part of the process.) The etched-foil wiring technique is studied in some detail and recent plating processes are discussed. Some base materials are examined, p.t.f.e.-impregnated glass-fibre laminates having the best electrical properties of materials developed so far.

Printed-wiring systems form the basis of automatic component-assembly techniques, which themselves require the development of suitable components and involve the standardization of certain parameters such as body size, axial design, lead diameter, and finishes for easy soldering. Several automatic soldering systems are in use.

The development of microwave circuits is mentioned and special techniques for high-temperature operation of printed wiring up to 500°C are explained.

The reliability of present-day printed wiring is examined. Trends towards future developments include progress in the microminiaturization field—where true printed circuits are involved.

Meeting of the Council on the 4th February 1960

THE following summary of reports received and decisions reached by the Council of The Institution at their meeting on the 4th February 1960 is issued on the authority of the President in a form approved by the Council. It will be understood that this report does not purport to be a complete account of the matters discussed at the meeting as some items must necessarily be regarded as *sub judice*.

Mr. A. C. Hartley, C.B.E.

Before starting their formal business the Council stood in silence in tribute to the memory of the late Mr. A. Clifford Hartley whose death had occurred on the 28th January 1960. At the time of his death Mr. Hartley was President of The Institution of Civil Engineers. He was President of The Institution of Mechanical Engineers in 1951–52. It was resolved that a letter of condolence be sent to the Council and Officers of The Institution of Civil Engineers.

Membership

Taking into account elections up to the 1st February 1960 it was recorded that the total membership of The Institution at that date was 45599.

Parsons *Turbinia* Memorial Fund

In passing on the Finance Committee's reaction to an appeal by the North East Coast Institution of Engineers and Shipbuilders for support towards a fund being raised for the reconstruction and rehousing of the *Turbinia*, Mr. C. T. Melling, Chairman, reported that although his Committee were in sympathy with the purpose of the appeal they were unable to recommend that the Council should contribute in view of The Institution's present financial commitments. In the circumstances, the Council agreed to accept the Committee's view.

Investments

The Council approved a further recommendation from the Finance Committee that, in exchange for £1000 3½% Paisley Redeemable Stock 1958–60 held by the I.M.E.A. Scholarship Fund and now due for repayment, an offer from the Burgh of Paisley of 5½% bonds due for repayment on the 15th May 1965 be accepted.

Membership of Joint Groups

The Joint Oversea Activities Committee of the three major engineering institutions had put forward a proposal for widening the activities and membership of existing Joint Groups, designed to assist in the development of national engineering societies in Commonwealth countries achieving or about to achieve independence.

It was proposed that, should a Joint Group Committee so wish, the membership of a Group could be expanded to include, in addition to Corporate and non-Corporate members of the three major engineering institutions in the United Kingdom, qualified engineers who are members of the bodies comprising the Commonwealth Engineering Conference or EUSEC. The title of any Group receiving permission to expand in this way would be changed to the '. . . Group of Professional Engineers, sponsored by The Institutions of Civil, of Mechanical and of Electrical Engineers of Great Britain', and new regulations would be drafted for use by such Groups.

It was considered essential that wherever possible the Chairman of a Joint Group should be a full member of one of the three British institutions, but that the Councils should have discretionary power to approve the election to the Chair of an Associate Member if circumstances rendered this necessary.

The Council welcomed and approved this proposal and agreed to seek the views of the Joint Group Committees.

Joint Group in Aden

A further recommendation from the Joint Oversea Activities Committee was approved, authorizing the formation, and the servicing by The Institution, of a new Joint Group in Aden. There were sufficient members of the three institutions in Aden to support a Group's activities, and exploratory meetings had been well attended.

Application under Bye-Law 42(iii)(e)—practice in Australia

The Council granted a request from a member of The Institution in regular practice as a consulting engineer in Australia for permission to conform with the usage there customary, in accordance with the proviso to this Bye-Law, by publishing an announcement of the 'professional card' type.

Honorary Membership and the Faraday Medal

On the recommendation of the President's Advisory Committee, the Council made the following elections to Honorary Membership of The Institution for 1960:

Col. B. H. Leeson, C.B.E., T.D., PAST-PRESIDENT, in recognition of his extensive contributions to the application of electrical science and engineering in the manufacture of electrical plant and equipment, to the development of co-operative effort within the electrical industry and to the training of electrical engineers, and of the services he has rendered to The Institution over nearly half a century.

Dr. Richard L. Hearn, B.A.SC., LL.D., for his notable contributions in the development of electricity generation and its supply for the benefit and use of mankind, particularly in Canada, and for the part he has played in international co-operation in this field.

Dr. Hearn's election was made under the terms of Bye-Law 10 which empowers the Council to elect, once in every period of three years, an additional Honorary Member who is not, at the time of his election, a member of any class of The Institution.

The Council also made the 38th award of the Faraday Medal to:

Sir George P. Thomson, D.SC., F.R.S., in recognition of his outstanding contribution to the advancement of electrical science, of the leadership in research which he has given to others in this field, and of his inspiring services to education in science and technology.

Conference on non-destructive testing in electrical engineering

This had originally been arranged as a symposium lasting two days, but it was now reported that the Measurement and Control Section Committee considered that three days would be required to accommodate the 40 or so papers which it was expected to include in the programme. On this basis the meetings would fall within the definition of a 'conference', and the Chairman of the Papers Committee, Mr. O. W. Humphreys, reported that his Committee wished to support the Section Committee's application for this extension. The Council gave their approval to the proposal and noted that the conference would be held from the 8th to 10th November 1961 (see p. 187).

Committee appointments

The Council approved recommendations from the General Purposes Committee and the Education and Training Committee with regard to appointments and nominations to various committees, details of which will appear in the *Journal* in due course in the section devoted to Announcements to members.

Scholarship Regulations

Prof. H. E. M. Barlow, Chairman of the Scholarships Committee, introduced for approval by the Council the revised Scholarship Regulations which his Committee had prepared. Changes in the Regulations included the introduction of sections dealing with the John S. Robinson Memorial Fund and the Mervyn J. P. O'Gorman Memorial Fund, together with amendments to Regulations 11 and 12 designed to enable holders of technical state scholarships and county major awards to receive a supplementary award of a small amount. The Council approved the revised regulations and gave their authority for these to be published.

Annual Dinner

The Council noted with pleasure that Sir George Thomson, the new Faraday Medallist and President of the Institute of Physics and of the British Association, had agreed to propose the toast of The Institution at the Annual Dinner of The Institution on the 25th February 1960.

The issue of tickets to non-member guests had been stopped early in January and there was now a waiting-list for returned tickets.

Diamond Jubilee of the Scottish Centre

The President spoke of the celebration of the Scottish Centre's Diamond Jubilee which he had attended, with the Secretary, in Glasgow on the 28th January 1960 and at which he had formally received a signing desk presented by the Centre to stand in the entrance hall of the Institution building at Savoy Place as a companion to that presented by the North-Eastern Centre, referred to at the previous Council meeting (see pp. 101 and 137 of the February 1960 *Journal* and p. 197 of this issue).

100th anniversary of the Institution of Austrian Architects, Consulting and Civil Engineers

Mr. R. H. Phillips, T.D., agreed to represent the Council at the celebration of the 100th anniversary of the Institution of Austrian Architects, Consulting and Civil Engineers which is being organized by the Austrian Chamber of Engineers in Vienna from the 1st to 4th June 1960.

621.311.1

Problems and achievements of Électricité de France

This article deals with some important differences between the electricity supply industry of Great Britain and that of France (nationalized a year earlier).

Because the methods of generating electricity and its use by consumers are different the two system maximum demands do not coincide. This has led to the projected cross-Channel link which will be of considerable advantage to both countries. France's achievements in h.v. transmission, together with the complications of load-factor improvement and some comparisons in development trends, are also discussed. The article is based on part of Mr. Harley's Chairman's Address to the West Wales (Swansea) Sub-Centre, delivered at Swansea on the 8th October 1959 (see February 1960 Journal, p. 137).

J. HARLEY, MEMBER

In France approximately half the total production of electricity is generated by water power, almost all the hydroelectric stations being situated in the mountainous regions of the south: in the Alps, the Central Massif, the Pyrénées, and also on the Rivers Rhine, Rhône and Durance where 'barrage' schemes are employed.

The steam stations are largely sited in the coalfields of the industrial north. In order to conserve coal, which is expensive and rather inferior in quality, the greatest possible use is made of hydroelectric power stations which produce cheaper electricity. Fig. 1 shows the locations of some of these stations. In Great Britain only a very small proportion of our electricity is generated by water power, mostly in the North of Scotland Hydro-Electric Board's area. These different generation characteristics, coupled with the fact that the maximum demands of the two countries do not coincide, led to a strong desire to install a connection for the exchange of energy across the English Channel.

The cross-Channel cable

In June 1956 the former Central Electricity Authority approved a scheme for interconnecting its electricity system with that of Électricité de France. The project involves direct-current transmission through a submarine cable 35 miles long between Dungeness in Kent and Boulogne in France.

Operating at 200 kV it will have a transmission capacity of 160 MW in either direction. Convertor stations will be provided at Lydd and Boulogne where the direct current will be converted to alternating current connecting into the 275 kV and 225 kV systems of England and France respectively. Unless there are serious unexpected difficulties the project will be completed before the winter of 1960–61.

In Great Britain the 275 kV superimposed system at present being constructed (the Supergrid) will ultimately consist of over 1000 route-miles of overhead line, of which it is proposed eventually to operate a portion at 380 kV. In France in 1957 I saw work being carried out on a 380 kV overhead line, and since 400 kV is the highest a.c.-system voltage in existence today (discounting American experiments with 750 kV) it seems that France is well to the fore as far as h.v. transmission is concerned. In the spring of 1958 the line from Génissiat to Paris—277 miles long—was put into commission at 380 kV.

The total cost of the cross-Channel scheme is estimated to be approximately £4 million and is to be shared equally between Britain and France. The British contribution will be more than offset by a reduction in the amount of new generating plant otherwise required, which will save about £10 million, effecting a net saving of over £200 000 per annum.

Convertor stations will be manned, but remote control can be exercised from both sides of the Channel and decisions on the flow of power will take only a matter of seconds to put into operation.

Choice of direct current

There are several reasons for using direct current. In long-distance cable transmission of alternating current there are high losses. More cables are required, with a greater likelihood of external damage. Also they would have to be laid some distance apart, occupying a width of more than 2 miles on the sea-bed, which would raise other problems owing to the large number of telecommunication cables already there. The difficulties of maintaining a very accurately controlled frequency in both countries are avoided by using a d.c. link.

The electric field set up by a high-voltage submarine cable can affect the magnetic compasses of ships passing over it. A similar power link has been in operation since 1954 between Sweden and Gotland, but running due east–west it does not disturb magnetic navigation and therefore a single cable was used to carry one pole of the d.c circuit, the sea acting as a conductor for the return current.

The English–French cable route runs roughly north-west to south-east, and a single cable system would have undesirable effects on navigation in the Channel. In consequence two cables will be used, one for each pole of the circuit, laid close together, each compensating the other's magnetic field.

Development trends

The total consumption of electrical energy in France increased from 57 700 million kWh in 1957 to 62 200 in 1958, an increase of 7·8%. A similar increase occurred in Great Britain during that year.

Percentage increases for the previous years were:

	France	*Great Britain*
1957	8·5	6·7
1956	8·8	9·4
1955	9·4	11·8

In the ten years from 1948 to 1958 the increase in France was 111·5%.

This trend agrees reasonably closely with that in this country but the consumption and maximum demand per head of population in France are lower than in such countries as Western Germany, Great Britain, the United States and Canada. In lagging behind France is left with a considerable leeway to make up in construction work and in capital expenditure.

Hydroelectric power

In 1958 hydroelectric stations in France accounted for 32200 million kWh, which is 51·7% of the total production; in 1957 the percentage was 43.

There is a fluctuation possible each year as a result of variations in rainfall and consequently in the amount of water available. For example in 1958 water availability was 7% above the average, and full use was made of this additional water for generation purposes with beneficial effects on the country's economy.

Thermal generation

During each year generation by coal is kept to a minimum. Increasing use is being made of natural gas, thus adding to the total amount of electricity obtainable from thermally operated stations. A third of the output of the natural-gas source at Lacq in the Pyrénées is reserved for the production of electricity. A new station using the gas from Lacq was started at Nantes-Cheviré and three others are projected.

In 1957 I was informed that it will be more economical to pipe gas the considerable distance from Lacq to the north of France than to generate electricity at the source and transmit it to the same districts. Plans for laying the necessary pipes were in hand. I have recently been informed that they are now laid to Montereau in the southern environs of Paris and are in service.

Gas is quite widely used in France, and it is interesting that consumers of bottled gas in that country number some 6 million as against approximately 500000 in Great Britain.

The investigation into the possible use of tidal power in the Rance estuary and the Bay of Mont-St.-Michel is at present in abeyance because of the proposals to pipe gas from the Sahara across the Mediterranean to Southern France.

Electricity from nuclear reactors

A very small amount of electricity is being supplied to the national Grid by three gas-cooled natural-uranium graphite-moderated reactors owned by the Commissariat à l'Énergie Atomique at Marcoule. Two similar reactors, but in this case designed specifically for electricity production, are under construction for Électricité de France at Avoine near Chinon. The first, with a capacity of 60 MW, was to have been commissioned early in 1960 and the other, of 170 MW, in 1961 but I understand that owing to trouble in erection the work is a year behind schedule.

There is programmed for completion by 1965–66 additional nuclear power of 850 MW, but because of the abundance of water and gas resources the nuclear-energy programme is only exploratory and for training engineers.

In comparison it is estimated that by 1966 the Central Electricity Generating Board covering England and

1 *The hydroelectric power stations of Électricité de France are shown by black circles*

Black squares indicate nuclear power stations. There are many other hydroelectric stations not shown on this map

Wales (excluding Scotland) will have about 3000MW of nuclear-power-station capacity. This will be generated by seven stations.

Energy storage and load factor

As we are only too well aware, the most serious disadvantage any supply industry has to face is the inability to store electricity in large quantities. There are various methods of storing energy but none of the methods known today seems likely to become suitable for large-scale application except perhaps pumped storage which is being developed in this country in North Wales and Scotland. For example Blaenau Ffestiniog should enable 300 million kWh to be sent out each year from its 300MW station during peak hours.

It is interesting to recall that pumped storage was advocated in 1920 by Prof. Bailey, who was at that time lecturing in Edinburgh, and that soon afterwards the first scheme in this country was put into operation at Walkerburn with a load of 300h.p.

The alternative is to improve the load factor, and although Électricité de France are doing a little with pumped storage they seemed to me to be making more serious efforts to improve their national load factor.

For example their tariffs provide for a variation in the price of the kilowatt-hour not only during peak and off-peak hours but also during 'full hours'. These hours vary in different parts of the country and a typical example would be as follows:

peak hours	7 a.m.–9 a.m. and 5 p.m.–7 p.m.	from the 1st November
off-peak hours	10 p.m.–6 a.m. and all day Sunday	to the 1st March
'full hours'	all the hours not defined above	

A further distinction is made between summer and winter months. In the domestic tariff the number of primary kilowatt-hours at the higher rate is again varied according to season. The new industrial tariff (the *tariff vert*) provides advantages to large consumers with a high load factor.

We must not forget the need to overhaul plant annually, and the time required for this work imposes a ceiling on the economical and practical load factor at something in the region of 80%. However no supply industry has reached a figure anywhere near this so far. Obviously therefore some improvement is desirable and worth striving for. Furthermore a higher load factor will be progressively of greater value in future for obvious reasons.

Since hydroelectric power in France is cheaper and has the disadvantage of not being constantly available in maximum quantities throughout the year, the load-factor-improvement problems of Électricité de France are quite complicated.

For the reasons referred to earlier and because of the different conditions obtaining in France, much excellent work has been and is being done by Électricité de France in the generation of electricity by water power. Achieving 50% of their production by this means has necessitated much energy and thought being devoted to transmission problems in order to transport efficiently large blocks of power across great distances and at very high voltage.

Use of imagination

An examination of the achievements of others shows that although their problems may differ they too are successful in resolving them. It should also be noted that similar problems can have quite different solutions. I have endeavoured to present in this article the way in which a particular set of problems is being attacked in another country, and thus provide justification for my contention that we all need to broaden our outlook and thoughts by studying with an open mind the methods of others.

This course will in addition assist us to avoid duplication of effort in searching for solutions to problems which have already been solved. It is most important that we direct all our efforts to moving forward. In looking forward we must remember that, even as in Biblical times, 'now we see through a glass, darkly; . . . now I know in part'.

We need initiative to couple with our industry; we need invention so that we improve and do not just imitate; we need insight as well as interest; and I would stress our need for ideals as well as ideas. Perhaps even more important is the need in the world of today for imagination.

In his Epilogue to 'St. Joan' George Bernard Shaw says 'Must then a Christ perish in torment in every age to save those who have no imagination?' Are there any with no imagination, or is it simply that there are some who do not use it? Without imagination, science and technology could not have advanced as they have, and if we cease to use imagination then progress must come to a sudden and irrevocable stop.

Summary

When it was established that the incidence of the system maximum demand of Électricité de France was not the same as that of Great Britain the possibility of linking the two countries by a submarine cable was examined. It was unlikely that the two demands would ever coincide because of the different use made by consumers of electrical energy in the two countries and, more conclusively, because of the different generation methods.

France is developing the large quantities of water power it has available. In addition to generating about half its electricity from water power France is exploiting the immense quantities of natural gas obtainable from the Pyrénées and more recently the reserves of gas discovered in the Sahara. In Great Britain we lack these ample natural resources so the need for coal and nuclear power in France is not as great as ours. Nevertheless it is as important to the French as it is to us to make every endeavour to improve the system load factor, and to this end they have adopted rather intricate tariffs.

Wiring Regulations—recent interpretations

(Issued on the 8th March 1960)

THE 13th edition of the Regulations for the electrical equipment of buildings was issued on the 1st September 1955, and amendments were approved by the Council of The Institution having effect from the 15th December 1958. The following abstracts of interpretations, the eighth group to be published,* are of general interest and involve clear-cut issues.

Inquiry 57 *Regulation* 229

May the type of cable known as 'p.b.j.' be used for wiring between buildings? It is argued that such cable is not acceptable for wiring between buildings in close proximity to each other, as for example a farmhouse and its outbuildings. Where the distances may be greater and the installation may be termed to be 'an overhead line', then the requirements of the Overhead Line Regulations need to be observed and, subject to restrictions on height etc., the use of 'p.b.j.' cables would, it is understood, be permitted.

Regulation 229 would appear to recognize the use only of the systems described therein.

Reply

For consumers' wiring between buildings only those systems referred to in Regulation 229(B)(i)–(v) may be described as complying with the Regulations. As is pointed out on pp. 3–4 of the Introduction, however, overhead lines and underground cables in consumers' installations are not fully dealt with in The Institution's Regulations, and for overhead lines in Great Britain the requirements of the Overhead Line Regulations should be observed. Overhead lines coming within the scope of the Overhead Line Regulations may, subject to the requirements of those Regulations, have lightly-insulated or bare conductors.

For guidance on good practice in the wiring of farm and horticultural installations, reference should be made to British Standard Code of Practice CP 325, in the preparation of which The Institution collaborated. It may be noted that B.S. 446 'Braided cables with copper conductors for overhead transmission lines', which is referred to in the Code, has now been withdrawn as obsolete.

In Codes of Practice for Telecommunication Services which have recently been revised (e.g. CP 327.101—'Telephones and telegraphs—public services' and CP 327.102—'Telephones and telegraphs—private services') references to 'p.b.j.' cables have been replaced by references to p.v.c.-covered or p.v.c.-insulated open wires, brief specifications of which are included in the Amendment to the two Codes mentioned above, published on the 19th June 1957. A draft British Standard for plastic-covered conductors is also being prepared.

Inquiry 58 *Regulation* 314

It is not clear whether the requirements of this Regulation apply to floor-warming installations for domestic premises. Where the associated thermostats are of a type not fitted with a switch, isolation of each floor-warming circuit can be achieved only by withdrawing the appropriate circuit fuse at the distribution board, or by the controlling main switch-fuse. Do such circuits come within the scope of Regulation 314 and thus require a switch, or the equivalent, in addition to any automatic-control device?

Reply

Although electrical floor-warming systems are not specifically dealt with in the Regulations (except in Regulation 230 as to heating wires and cables) the definition of 'appliance' on p. 7 would appear to include a floor-warming circuit, so that the requirements of Regulation 314(A) would apply. This interpretation is supported by a reading of Regulation 314(A) in conjunction with Regulations 7 and 116(A). In circumstances such as those described, therefore, an isolating switch additional to any automatic-control device is necessary for compliance with the Regulations.

As to the position of this isolating switch, the use of floor-warming systems was not considered when Regulation 314(B) was made. A floor-heating installation in non-domestic premises could however be held to come under 314(B)(ii) which allows the switches to be installed in a separate room if so desired; and there seems no reason to think that equal freedom of positioning for floor-heating switches should not be allowed for domestic premises. In suitable circumstances, subject to compliance with Regulations 7 and 116(A), this would allow the switches to be situated at the consumer's control unit.

The use of a thermostat which is combined with a switch is an obvious way of meeting the requirements. Attention is called to the paragraph on p. 4 of the Introduction beginning 'Only proved materials . . .'

This question has been noted for consideration when the Regulations are next revised.

Inquiry 59 *Regulations* 318(B), 405(B), 405(C)

The Exemption to Regulations 405(B) and (C), which appears in the Amendments issued in December 1958, has resolved the difficulty of providing for the use of electric shavers in bathrooms. These appliances are also frequently used in bedrooms, and for such situations a type of supply unit or socket, less elaborate than that provided for in B.S. 3052, appears to be satisfactory. A common type of supply unit incorporates an auto-transformer so that a 110 volt supply can be obtained if desired; does the use of such a unit in a bedroom contravene Regulation 318(B) which states that an auto-transformer shall not be used to supply a socket-outlet or any portable appliance?

Reply

The use of an auto-transformer to supply a socket-outlet or portable appliance does not comply with the requirements of Regulation 318(B) unless, for a portable appliance, the auto-transformer is contained within the appliance.

However, Regulation 318(B) was framed to prevent the danger which may arise from the use of an auto-transformer to supply apparatus (e.g. extra-low-voltage equipment) which

* Reprints of the earlier sets of abstracts remain available, price 6d. each post-free. Details of these may be obtained from the Secretary of The Institution

is not suitably constructed to withstand safely the application of the transformer input voltage in the event of a fault in the transformer circuit.

For an electric dry-shaver rated for 110 volts the danger referred to above may be but little greater than the risks normally attending the use of a shaver rated for and supplied direct from a 240 volt supply; these risks are guarded against by the requirements of the Regulations generally, which apply equally to 110 and 240 volt systems. For a shaver supply unit intended to be installed in a bathroom, the use of a double-wound transformer is essential. Only a unit complying with B.S. 3052 may be used in such a situation. (See Regulations 405(B) and (C). Exemption, and Regulation 601.)

This question has been noted for consideration when the Regulations are next revised.

Inquiry 60 *Regulation* **410(B)**

Regulation 410(B)(ii) concerning differential earth-leakage circuit-breakers of the current-balance type specifies that they should operate when the leakage current to earth attains not more than 15% of the rated current or 5amp, whichever is the greater.

It might be expected that these words should read 'whichever is the smaller', in order to ensure that for heavy rated currents the circuit-breaker will remain sensitive enough (operating limit 5amp) and also that for circuit-breakers with rated currents below 33·3amp the sensitivity will be in relation to the rated current.

An explanation of the wording referred to will be much appreciated.

Reply

It is confirmed that the words 'whichever is the greater' in Regulation 410(B)(ii) correctly express the intention of the Wiring Regulations Committee. It is of interest to recall the wording of Note 3 to Regulation 1006—Earth-leakage protection, of the 12th edition of the Regulations, which reads as follows:

'**Note 3**—The earth-leakage protection device may be of a type operated by a rise in voltage between the metal to be protected and earth, in which case it should be arranged to operate with a rise not exceeding 40 volts, or, alternatively, may be of a differential type arranged to operate when leakage current to earth attains 15% of the rated current for the circuit or 5amp, whichever is the greater.'

It will be clear that Regulation 410(B)(ii) of the 13th edition is anticipated by the latter part of the above Note. It will also be clear that during its currency the above Note (which did not, of course, constitute a requirement of the Regulations) recommended 15% of the rated current and 5amp as absolute values of current at which a differential-type earth-leakage circuit-breaker should operate.

When the subject-matter of the Note was embodied in the text of the Regulations in the 13th edition, the words 'not more than' were inserted after the word 'attains'. By this means the figures quoted became upper limiting values, and the use if desired of differential circuit-breakers of higher sensitivity was not precluded.

This question has been noted for consideration when the next edition of the Regulations is prepared, in case revision is desirable in the light of the characteristics of the types of differential earth-leakage circuit-breaker which may then be available.

ELECTRIC LOCK

An electrically-operated combination door lock has recently been designed by electronic engineers of the United Kingdom Atomic Energy Authority.

The outer panel of the lock carries up to 12 buttons or switches, four of which, depressed two by two in the right order and within a preset space of time, will open the lock by operating electrical relays. The sequence of the actuating buttons and their positions can be very easily reset and the code can be changed as often as required without inconvenience. The exact number of combinations possible with 12 keys of which four are taken two by two, order not counting, is 4356.

The lock is tamper-proof and foils attempts to open it by trial-and-error methods because, if the wrong buttons are pressed, or the right buttons but in the wrong sequence, an alarm is sounded.

Television in the Border country

The Independent Television Authority plans to build two new transmitting stations to serve the Border country. One will be near Carlisle and will cover an area round the Solway Firth from Wigtown to St. Bees Head, taking in the greater part of Kirkcudbright and Dumfriesshire, most of Cumberland and a large part of Westmorland. The other station will serve the Tweed area between the Lammermuirs in the north and the Cheviots in the south.

The Authority hopes to begin programme transmissions from the Carlisle station early in 1961 and from the other towards the end of 1961. Approximately half a million people live in the areas to be served by the two stations.

Encouragement for telephone users

In an after-dinner speech on the 17th February 1960 the Postmaster General deplored the low calling-rate of the average residential telephone-subscriber, who uses his telephone to make, on average, about one call a day. Including business users the United Kingdom rate is 500 calls a year per telephone; for Canada, the United States and Sweden the figure varies from 1700 to 1000.

Use of the telephone must be encouraged, he said, and the cost of provision—about £110 per telephone—must be reduced. Perhaps the greatest savings were to be found in cable development.

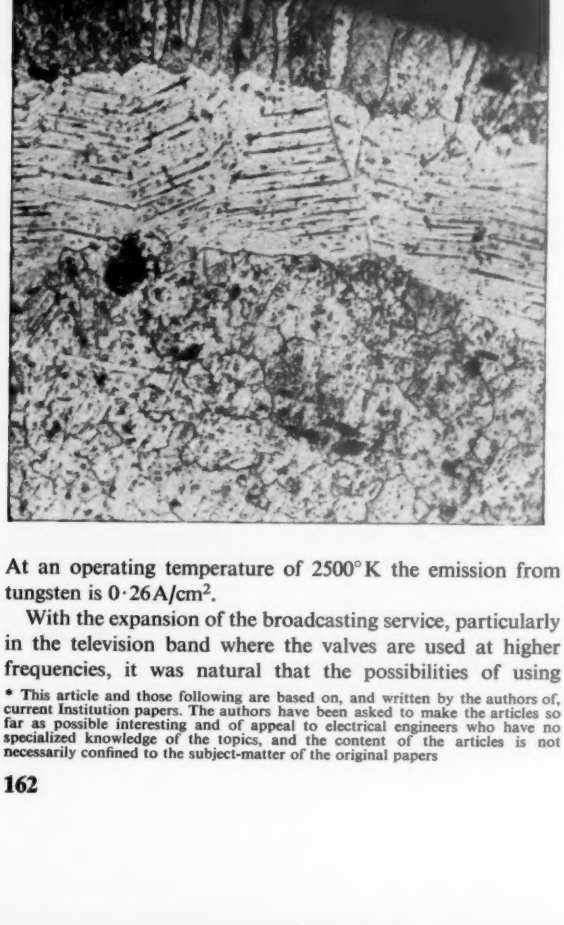
He announced that the remaining 1000 manually operated exchanges in the United Kingdom would be converted to automatic working by 1970. All the inland systems will have 'twopenny telex' by the end of 1960, and telex dialling to major Western European countries should be completed during 1961.

HIGH-POWER TRANSMITTING VALVES WITH THORIATED FILAMENTS

A brief account of an Electronics and Communications Section paper (3200) entitled 'High-power transmitting valves with thoriated filaments for use in broadcasting' by H. S. Walker, M.B.E., W. H. Aldous, B.Sc., Associate Members, R. G. Roach, B.Sc., J. B. Webb, D.F.H., Associate Member, and F. D. Goodchild, B.Sc.(Eng.), Member. The paper is published this month in Part B of the Proceedings. Messrs. Walker and Webb are with the British Broadcasting Corporation, Mr. Aldous is at the Research Laboratories of the General Electric Co. Ltd., Mr. Roach is with the English Electric Valve Co. Ltd., and Mr. Goodchild is with Standard Telephones and Cables Ltd.*

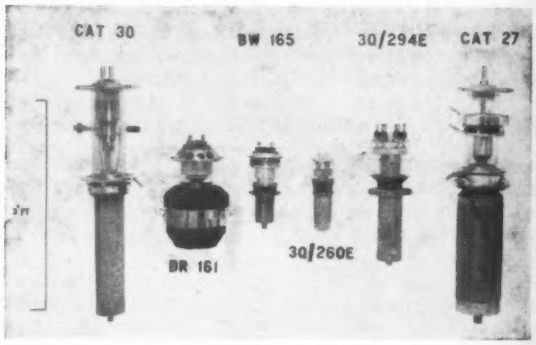
TRADITIONALLY, high-power transmitting valves used in broadcasting were fitted with cathode filaments of pure tungsten, since the high temperature at which this metal could operate without excessive evaporation gave the best compromise between emission and life for the materials available.

1 *Photomicrograph of wire section showing decarburized surface*



At an operating temperature of 2500°K the emission from tungsten is $0{\cdot}26\,A/cm^2$.

With the expansion of the broadcasting service, particularly in the television band where the valves are used at higher frequencies, it was natural that the possibilities of using thoriated tungsten in place of pure tungsten as an emitter should be examined, since thoriated tungsten gives an emission of $3\,A/cm^2$ at 2000°K. Furthermore, it was known that the end of these valves was not the result of burning-out of the filament due to evaporation, as is the case with the tungsten



2 *Six types of thoriated-filament transmitting valve*

filament, but was brought about by loss of emission owing to evaporation of carbon from the filament, the carbon having been added as an essential process for the development of the full emission efficiency.

The electron-emitting properties of thoriated tungsten were discovered in 1914 by Langmuir, but the material was not really established as a commercially useful electron emitter until about ten years later, and then only in low-power valves, when the carburizing process became recognized.

Use of zirconium

The exploitation of thoriated tungsten in high-power valves awaited the introduction of getters which could maintain a good enough vacuum in the vicinity of the filament. This was achieved only when zirconium became available, as this metal could be placed in the hot part of the valve where it was most effective. Using such material, valves of the largest size have been made with thoriated-tungsten cathodes, and new designs of valve have appeared which would have been quite impossible with pure tungsten.

Use of the thoriated-tungsten-filament valve has made much greater cathode emission available with considerable reduction in power consumption for heating the filaments. These considerations are highly important to a big valve user like the British Broadcasting Corporation where running costs due to valve maintenance and the cost of filament heating are important items of expenditure. The paper describes the savings that can be effected in a typical installation using four 100kW transmitters converted from pure-tungsten-filament valves to thoriated-tungsten-filament valves.

* This article and those following are based on, and written by the authors of, current Institution papers. The authors have been asked to make the articles so far as possible interesting and of appeal to electrical engineers who have no specialized knowledge of the topics, and the content of the articles is not necessarily confined to the subject-matter of the original papers

In the paper is outlined the technology of the thoriated-tungsten emission and processing and the carburizing process, which is usually carried out by heating the filaments to about 2300°K in an atmosphere of volatile hydrocarbon. As the carbide is brittle, only about 25% of the cross-sectional area is carburized, leaving a core of tungsten to give strength to the wire (Fig. 1).

The development of high-power valves incorporating thoriated-tungsten filaments has involved considerable work in eliminating grid emission. Special treatment has therefore had to be given to the control-grid surface to prevent primary grid emission.

The paper also includes detailed results of a number of years' experience in the field with six different types of valve (Fig. 2) introduced into the broadcasting service.

621.385.3 : 621.396.97

V.H.F. field strengths over the Irish Sea

A brief article based on an Electronics and Communications Section paper (3169) entitled 'V.H.F. field-strength measurements over paths in the Irish Sea involving mountain obstacles: their application to a particular television-channel-sharing problem' by J. K. S. Jowett, B.Sc.(Eng.), Member. The paper is published this month in Part B of the Proceedings. The author is in the Post Office Engineering Department.

THE study of the propagation of radio waves is always interesting if only because from time to time it reveals quite unexpected results. Classic examples are the propagation of high-frequency waves to long distances by a process of refraction in the ionosphere and, of more recent discovery, the propagation of v.h.f. waves to distances well beyond the horizon. While the latter phenomenon has been largely accounted for by processes of reflection or scattering taking place at irregularities in the troposphere there are other important contributing effects such as that of diffraction around irregular ground which may not yet have received the attention that they deserve.

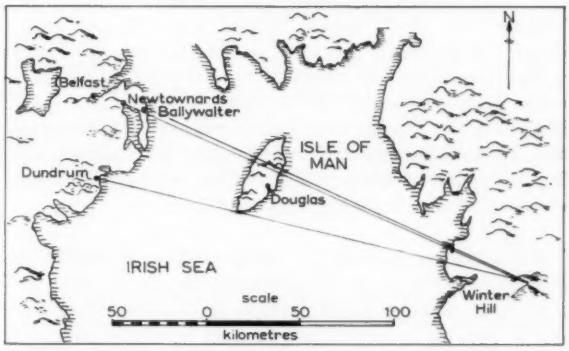
Object of study

One particularly interesting case of ground diffraction is afforded by a propagation path which is obstructed by a high mountain ridge but is otherwise relatively smooth. Such a type of path merits study not only because of its intrinsic simplicity but also because practical problems do occur in which it is required to determine the strength of v.h.f. signals transmitted over a mountain ridge. A specific example results from the television-channel sharing between two I.T.A. stations, one at Winter Hill in Lancashire and the other at Black Mountain in Northern Ireland. Some of the paths studied in this connection are illustrated in Figs. 1 and 2.

Fig. 3 shows a cross-section of the obstructing ridge of the Isle of Man as it would appear when projected along the east coast of Northern Ireland.

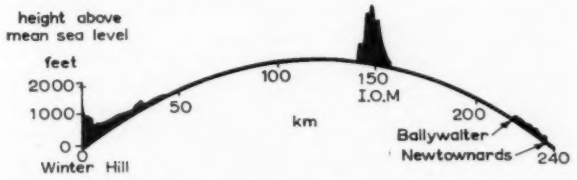
On the basis of standard tropospheric-propagation curves it was estimated that the use of the same channel for these two stations would not produce significant co-channel interference. But it was necessary to confirm that effects which might take place owing to the obstructing mountain range of the Isle of Man would not enhance the propagation of interfering signals to any harmful extent.

The experiments described in the paper therefore had a twofold object: to obtain more data on extreme examples of paths providing v.h.f. propagation over mountain ridges for general planning use, and to investigate certain particular paths across the Irish Sea to ensure that adequate protection against co-channel interference would be afforded to viewers served by the new Black Mountain television station. Some of the paths studied involved over-sea propagation only.



1 *Map showing paths studied*

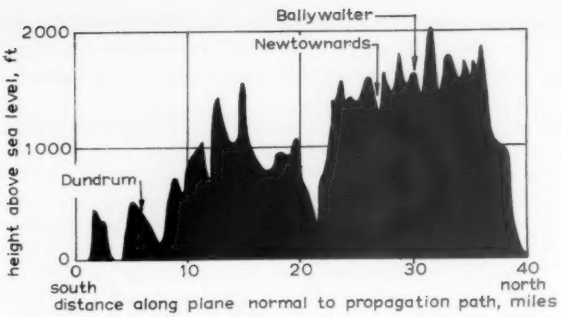
2 *Profile between Winter Hill and Newtownards also showing position of Ballywalter*



Other paths of similar length also involved over-sea propagation but with the difference that a high obstructing ridge intervenes near the centres of the paths.

Interesting results

A comparison of the results of long-term field-strength measurements over such different paths has revealed a number of points of interest. It has been shown for example that the ridge-obstructed paths gave median signal levels equal to or slightly greater than those observed over the



unobstructed paths. Moreover the range of signal fading experienced was generally much less in the case of the ridge-obstructed paths owing, it seems, to the predominating effects of diffraction at the ridge. The results over the various paths studied are expressed in a suitable statistical form in the paper.

The application of these studies to the specific channel-sharing problem has shown that the extent of any co-channel interference in the Black Mountain service area is likely to be small and within the generally accepted limits used in the planning of television-broadcast services. 621.391.812 : 621.397

3 *Projection of profile of Isle of Man ridge normal to propagation paths*

Gaseous discharges in high-voltage d.c.-cable dielectrics

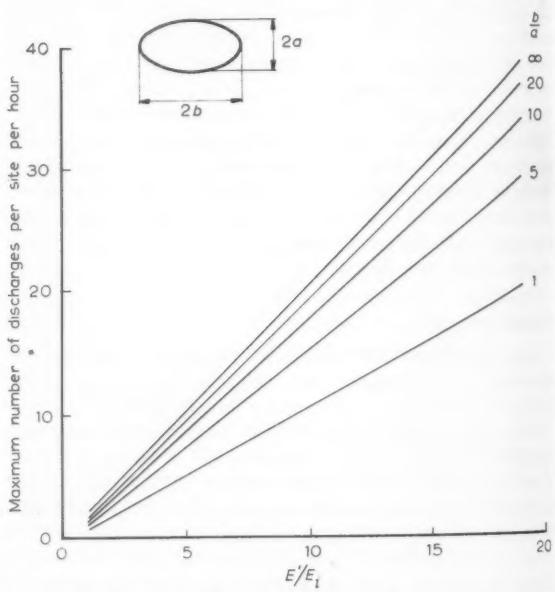
A brief article based on a Supply Section paper (3144) entitled 'Gaseous-discharge phenomena in high-voltage d.c.-cable dielectrics' by E. C. Rogers, M.Sc., A.Inst.P., and D. J. Skipper, B.Sc.(Eng.), Associate Members. The paper was published individually in January 1960 and will be republished in Part A of the Proceedings. It was read before the Supply Section on the 13th January 1960 at Savoy Place (reported on p. 194*). Mr. Rogers is, and Mr. Skipper was formerly, with British Insulated Callender's Cables Ltd. Mr. Skipper is now with the Central Electricity Generating Board.*

INTEREST in high-voltage d.c. cables has been stimulated in recent years by a number of projects involving the interconnection of large power systems by underwater routes. Where such cable connections exceed a critical length—estimated at about 40 miles for 132kV—a.c. transmission is made impracticable by the excessive charging current. Even when the distance involved is not too great direct current may be preferred, as in the proposed scheme to link the British and French supply systems by a cable across the Channel, since the necessity to synchronize the frequencies of the two systems is thereby avoided.

One factor that must be considered in the design of h.v. d.c. cables is the possible effect of discharges in gas-filled-cavities on the life of the dielectric. The importance of this effect in a.c. conditions has long been recognized and has resulted in the modern pressure-assisted h.v. a.c. cable in which discharges in the impregnated-paper dielectric are suppressed by the application of gas or oil pressure.

With direct current there is little doubt that discharges will be very much less frequent and the rate of damage correspondingly less than in comparable a.c. conditions. In h.v. d.c. cables it may thus be possible to utilize thermoplastic insulants such as polythene which cannot as yet be operated at high a.c. stresses because of the difficulty of eliminating discharges.

To investigate this possibility an assessment has been made of the importance of discharge damage as a mechanism of dielectric deterioration in d.c. conditions. Polythene was selected for study because of its known vulnerability to discharges and its translucence which permitted the use of an optical method of discharge detection.



1 *Calculated maximum repetition rates of discharges in oblate-spheroidal cavities in polythene*
$\epsilon_2 = 2{\cdot}3 \qquad \sigma_2 = 5 \times 10^{-15}$ mho/m

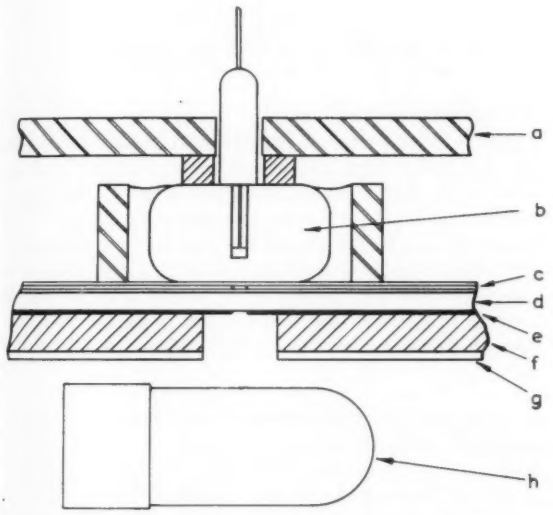
Calculation of the discharge repetition rate

The rate at which a dielectric is damaged by discharges depends on their repetition rate. When a dielectric containing

a gas-filled cavity is subjected to a d.c. stress there is a rapid succession of discharges as the stress is raised from zero to the steady value and then, with a perfect dielectric having infinite resistivity, no further discharges occur provided that the stress remains steady.

In practice all dielectrics have a finite resistivity, and so repetitive discharges do occur at intervals determined by the time required for the cavity to be recharged to the breakdown voltage by conduction through the dielectric. The steady-state repetition rate depends on the surface conductivity of the cavity walls, which is in general unknown, but is greatest when the surface conductivity is zero.

The maximum rate depends on the permittivity and conductivity of the dielectric ϵ_2 and σ_2, the shape of the cavity, and the ratio of the stress in the dielectric E' to the breakdown stress of the gas in the cavity E_i. Calculated values of the maximum repetition rate of discharges in a gas-filled oblate-spheroidal cavity in polythene are given in Fig. 1 for a range of cavity shapes and values of E'/E_i.



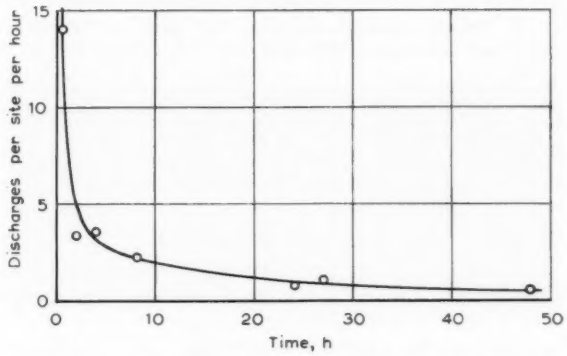
2 *Sectional elevation of test cell for measurement of discharge repetition rates*

a Tufnol clamping strip
b Brass h.v. electrode
c The sample
d Glass plate with transparent electrode on upper surface
e Mask
f Rubber sheet
g Lid of light-proof box
h Photomultiplier tube

Measurement of the discharge repetition rate

To confirm the theoretical work, direct measurements of the repetition rate of discharges in air-filled cavities in polythene samples were made by means of the equipment shown in Fig. 2. The samples consisted of three sheets of polythene placed face to face, the middle sheet being punched at its centre with a circular hole, so providing the cavity. Light emitted by the discharges in the cavity was detected by the photomultiplier tube, and the number of discharges was recorded by a simple counter circuit.

In all the tests the discharge repetition rate decreased with time until a sensibly steady value was reached after one to three days. A typical result is given in Fig. 3. This decrease is due to a similar variation in the volume conductivity of polythene caused by dielectric absorption.



3 *Variation of repetition rate of discharges in a cavity in polythene with time of application of stress (300 kV/cm)*

Accelerated life tests

In order to estimate the effect of a cavity on the d.c. life of a dielectric it is necessary to know not only the discharge repetition rate but also the number of discharges in the cavity which the dielectric can withstand. If this number is not greatly influenced by the frequency of the discharges it can be determined in a relatively short time by means of 50c/s life tests on samples containing artificially introduced cavities.

Care is needed in the design of these tests since changes in the conductivity of the cavity walls caused by the discharges themselves can result in the discharges becoming extinguished or intermittent. The damaging effect of a discharge probably depends on the stress in the dielectric on which it impinges as well as on the magnitude of the discharge, and so in the accelerated life tests the samples are subjected to an a.c. stress of peak value equal to the intended d.c. working stress.

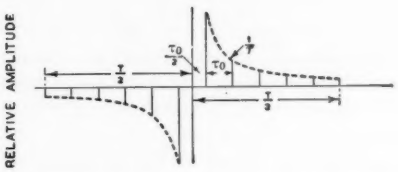
Life tests of this kind made on polythene samples containing air-filled cavities of up to 0·1 mm depth have shown that at 65° C and at stresses in excess of 150 kV/cm the polythene can withstand at least 2×10^8 discharges without failure. In probable working conditions in a polythene-insulated h.v. d.c. cable the steady-state number of discharges per site per hour is unlikely to exceed ten, and the time to failure caused by discharge damage should be greater than 10^7 h. This is very much longer than the normal working life of a cable of about 40 years.

621.315.211.2 : 621.315.61 : 621.387

Vestigial-sideband signals from quadrature network

A brief article based on an Electronics and Communications Section paper (3054) entitled 'A quadrature network for generating vestigial-sideband signals' by G. G. Gouriet, Member, and G. F. Newell, Associate Member. The paper was published individually in October 1959 and will be republished in Part B of the Proceedings. It was read before the Electronics and Communications Section at Savoy Place on the 11th January 1960 (see p. 191). Mr. Gouriet was formerly, and Mr. Newell is, in the B.B.C. Research Department. Mr. Gouriet is now with Wayne Kerr Laboratories Ltd.

ONE method of obtaining single- or vestigial-sideband signals consists of generating two double-sideband ones which because of the relative phases of their sidebands can be added to produce the required signal. For this the two carriers must have a phase relationship of $\pi/2$ radians and the two modulation signals must be in quadrature relationship.



1 *Amplitude distribution at taps along line*

Realization of 'quadrature'

The definition and significance of quadrature signals have been discussed by Gabor* who suggested a mechanical means of generating them. Six-terminal all-pass networks have been used to obtain approximate-quadrature audio signals but the present paper describes a linear electrical network suitable for use with television waveforms.

By definition two signals $s(t)$ and $s^*(t)$ are in quadrature if they are related by the pair of Hilbert transforms:

$$s^*(t) = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{s(\tau)}{t-\tau}d\tau \quad . \quad . \quad . \quad . \quad (1)$$

$$s(t) = -\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{s^*(\tau)}{t-\tau}d\tau \quad . \quad . \quad . \quad . \quad (2)$$

The term 'quadrature' arises because of the significance of the Hilbert transforms in terms of spectra; the equivalent operation is to change the phase of every Fourier component by $\pi/2$ radians, which amounts to multiplying the complex spectrum by the operator j in the negative-frequency domain and $-$j in the positive.

In seeking a network to perform this operation it is pertinent to inquire what its response would be to a Dirac function, or unit impulse, defined by the Fourier integral as:

$$\delta(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty}\varepsilon^{j\omega t}d\omega \quad . \quad . \quad . \quad . \quad . \quad (3)$$

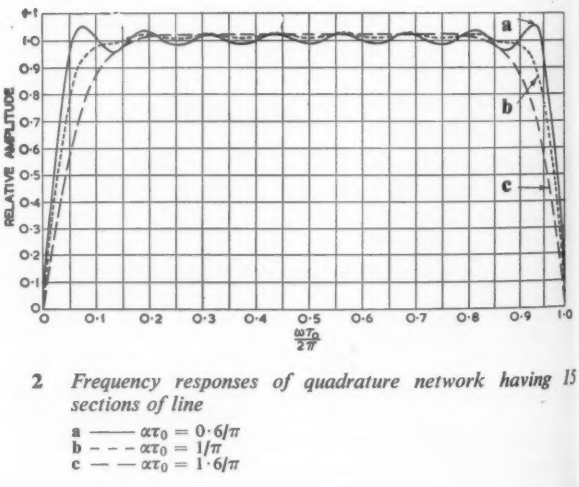
If in eqn. (1) $s(\tau)$ is replaced by $\delta(\tau)$ we obtain:

$$\delta^*(t) = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{\delta(\tau)}{t-\tau}d\tau = \frac{1}{\pi t} \quad . \quad . \quad . \quad (4)$$

by virtue of the properties of the Dirac function.

The quadrature network

Thus a linear 4-terminal network with an impulse response $1/t$ will produce a quadrature signal $s^*(t)$ when $s(t)$ is applied to its input. Such a network may be realized to the required accuracy by means of a delay line tapped regularly along its length with the output at each tap adjusted in amplitude and sign to be inversely proportional to the time-delay relative to the centre of the line (see Fig. 1). If the total delay is T and the interval between the taps is τ_0 the sum of all the outputs at the taps within the frequency band 0–$1/2\tau_0$ cycles per second will correspond to the signal $1/t$ between the limits $-\frac{1}{2}T$ and $\frac{1}{2}T$ and with the bandwidth restricted to $1/2\tau_0$ cycles per second. The network will of course introduce a fixed time-delay equal to $\frac{1}{2}T$.



2 *Frequency responses of quadrature network having 15 sections of line*

a —— $\alpha\tau_0 = 0{\cdot}6/\pi$
b - - - $\alpha\tau_0 = 1/\pi$
c — — $\alpha\tau_0 = 1{\cdot}6/\pi$

The spectrum response to unit impulse over the restricted band 0–$1/2\tau_0$ cycles per second is given by:

* GABOR, D.: 'Theory of communication', *Journal I.E.E.*, 1946, 93, Part III, p. 429

$$\delta^*[\omega, T] = \frac{1}{\pi}\int_{-T/2}^{T/2}\frac{\varepsilon^{-j\omega t}}{t}dt = \frac{2}{j\pi}\mathrm{Si}\left(\frac{\omega T}{2}\right) \quad . \quad . \quad (5)$$

As the length of the line T tends to infinity the spectrum tends to a value j for $\omega < 0$ and $-j$ for $\omega < 0$, which accords with the definition of quadrature stated above. For a finite length of line however the spectrum will contain ripples precisely analagous to those which occur in the time-response to unit step of an ideal filter of finite bandwidth. The behaviour is in fact identical except that time and frequency have been interchanged. In order to achieve a monotonic spectrum the 'tapering' function $1/t$ may be modified to approach zero at a suitably faster rate.

For example if the function $1/\pi t$ in eqn. (5) is replaced by $\varepsilon^{-\alpha|t|}/\pi t$ the modified spectrum approaches, with increasing line length:

$$\phi[\omega] = \frac{2}{j\pi}\arctan\frac{\omega}{\alpha} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

An even better alternative is to replace $1/\pi t$ by the function:

$$f(t) = \frac{\alpha}{2}\operatorname{cosech}\frac{\pi\alpha t}{2}$$

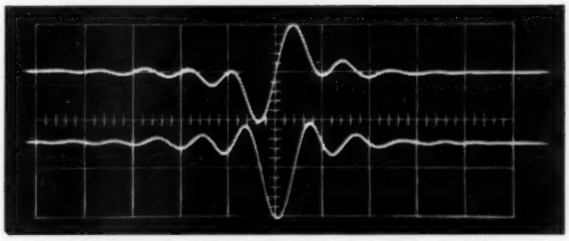
This provides a monotonic spectrum, for an infinite line length:

$$f[\omega] = \tanh\frac{\omega}{\alpha} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The practical network

These two spectra can be achieved approximately if the line is made sufficiently long for the contributions at the extremities to be negligible. The value of α is chosen to give the required frequency response near the origin. Fig. 2 shows f[ω] plotted as a function of normalized frequency $\omega\tau_0/2\pi$ for three cases of a 15-section network with $\pi\alpha\tau_0$ equal to 1·6, 1·0 and 0·6 respectively.

A line suitable for operation with a television signal has been constructed and a vestigial-sideband television signal has been produced by these means. The response of the practical line to unit impulse in the frequency band 0–3 Mc/s is shown in Fig. 3.



3 *Quadrature signals obtained with a practical line*
Input signal (top) $\simeq \sin x/x$

621.372.553 : 621.397.2

Rectifier modulators

A short account based on two Electronics and Communications Section papers (3051 and 3187) entitled 'Rectifier modulators with frequency-selective terminations, with particular reference to the effect of even-order modulation products' by D. P. Howson, M.Sc., Graduate, and Prof. D. G. Tucker, D.Sc., Member, and 'The input impedance of rectifier modulators' by Prof. Tucker. The papers were published individually in January 1960 and will be republished in Part B of the Proceedings. They were read before the Electronics and Communications Section on the 11th January 1960 at Savoy Place and a report of the meeting appears on p. 191. Mr. Howson is in the Department of Electrical Engineering, and Prof. Tucker is Professor of Electrical Engineering, University of Birmingham.

THE object in paper 3051 is to establish a basis for calculating the modulation products in rectifier modulators of the series, shunt and ring types (the circuit arrangements and effective circuits of which are shown in Fig. 1) and then to demonstrate and tabulate the conditions in which the three types of circuit have exactly the same performance. To do this without excessive complexity certain simplifying assumptions are made and it is found that the presence or absence of even-order modulation products has a big effect on the simplicity of solution.

In paper 3187 the methods are used to study the properties of the input impedances of the modulators, and it is shown that in general the input impedance, defined as the ratio of voltage to current at the applied frequency, has the unusual property of depending on the signal-source impedance from which it is measured.

The circuits are analysed as linear passive networks with some time-varying resistance elements; these are the rectifiers, which vary under the influence of the carrier voltage cos $\omega_p t$ and may be considered linear (i.e. independent of the signal $V\cos\omega_q t$) if the carrier amplitude greatly exceeds that of the signal.

The time-varying resistance function $r(t)$ is taken as a square-wave represented as a Fourier series:

$$r(t) = r_0 + \sum_{n=1,3\ldots} r_n \cos n\omega_p t$$

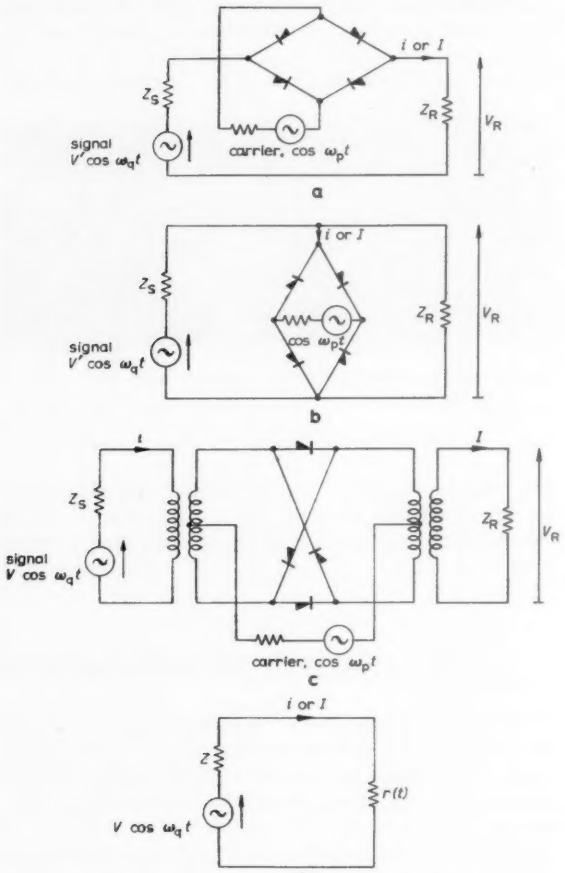
where $r_n = r_1(-1)^{(n-1)/2}/n$ and n is odd.

It is shown that considerable simplification of the circuit equations results from the further assumption that the external impedances Z (for series and shunt modulators) and Z_S and Z_R (for the ring modulator) are purely resistive (although not necessarily constant) at all frequencies of modulation products—whatever their values may be in between these frequencies.

It is also shown that with these assumptions the output loop of the ring modulator contains only odd-order

modulation products ($n\omega_p \pm \omega_q$ where n is an odd integer) and the input loop only even-order products ($l\omega_p \pm \omega_q$ where l is an even integer) together with the applied signal.

Therefore, using i for even-order currents and I for odd-order currents, subscripts $n\pm$ and $l\pm$ to indicate the sideband



1 *Circuit arrangements and effective circuit of rectifier modulators*

a series modulator
b shunt modulator
c ring modulator
d effective circuit of series and shunt modulators and in certain circumstances of ring modulator

For series modulator:
$V = V'$, $Z = Z_S + Z_R$, $V_R = iZ_R$

For shunt modulator:

$$V = V' \frac{Z_R}{Z_S + Z_R}, \quad Z = \frac{Z_S Z_R}{Z_S + Z_R}, \quad V_R = iZ \text{ (except at } \omega_q).$$

---

concerned, and R for the resistive values of Z it becomes possible to express the relationships of all three modulators by the same set of equations, one for each frequency, thus:

at frequency ω_q

$$V = i_0(R_0 + r_0) + \tfrac{1}{2} \sum_{m=1,3\ldots} (I_{m+} + I_{m-})r_m \quad . \quad . \quad (1)$$

at frequency $n\omega_p \pm \omega_q$

$$0 = I_{n\pm}(R_{n\pm} + r_0) + \tfrac{1}{2} i_0 r_n + \tfrac{1}{2} \sum_{k=2,4\ldots} (i_{k\pm} r_{|k-n|} + i_{k\mp} r_{k+n}) \quad (2)$$

and at frequency $l\omega_p \pm \omega_q$

$$0 = i_{l\pm}(R_{l\pm} + r_0) + \tfrac{1}{2} \sum_{m=1,3\ldots} (I_{m\pm} r_{|m-l|} + I_{m\mp} r_{m+l}) \quad . \quad (3)$$

where m is used generally as an odd integer and k as an even integer. In the case of the ring modulator, R refers to Z_S when the subscript is even and to Z_R when it is odd.

Vanishing of even-order currents

Now it is usually the current I_{1+} or I_{1-} which is required, and it is clear that the process of solution is likely to be complex in general. But it can be seen that, if it is known that all even-order currents are zero, eqn. (2) gives an explicit solution for any odd-order current in terms of i_0, and by substitution in eqn. (1) to get an expression for i_0 in terms of the applied signal voltage V a simple solution for the required current is immediately obtained in terms of V.

Thus it is important to know the conditions which make the even-order currents vanish. These are shown to be:

(1) Z or Z_R is a constant resistance at all odd-order frequencies

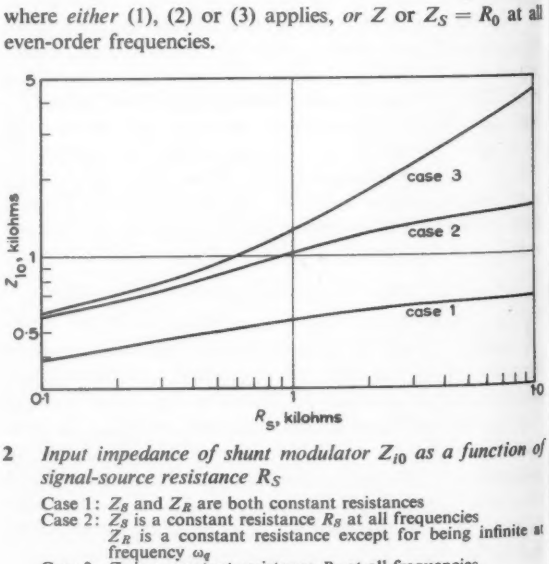
or (2) $R_{l\pm} = \infty$ for all l

or (3) $R_{n\pm} \ll r_0$ for all n.

Alternatively, if Z or Z_S is a constant resistance at all even-order frequencies including ω_q, then, although even-order currents exist, the odd-order currents do not interact, so that the solution for $I_{n\pm}$ is the same as for (1), (2) and (3) above, namely:

$$I_{n\pm} = \frac{-\tfrac{1}{2} V r_n}{(R_{n\pm} + r_0)(R_0 + r_0) - \dfrac{\pi^2}{16} r_1^2} \quad . \quad . \quad (4)$$

where *either* (1), (2) or (3) applies, *or* Z or $Z_S = R_0$ at all even-order frequencies.



2 *Input impedance of shunt modulator Z_{i0} as a function of signal-source resistance R_S*

Case 1: Z_S and Z_R are both constant resistances
Case 2: Z_S is a constant resistance R_S at all frequencies
Z_R is a constant resistance except for being infinite at frequency ω_q
Case 3: Z_S is a constant resistance R_S at all frequencies
Z_R is infinite except at frequency $\omega_p + \omega_q$

A dual set of equations in terms of voltages and admittances can also be obtained with corresponding conclusions.

Tables of examples

In paper 3051 many examples are tabulated, the correspondence with practical conditions is shown and experimental results are given. These results are used in paper 3187 to determine the input impedances of modulators as defined by v_0/i_0 where v_0 is the voltage of the input signal ω_q measured across the input terminals of the modulator and i_0 is the current at this frequency flowing into the input terminals. A ring modulator terminated with Z_R equal to a constant resistance at all odd-order frequencies is exceptional in giving an input impedance which is a constant resistance independent of the signal-source impedance; but all other cases give an input impedance dependent on the nature and value of the signal-source impedance.

Numerous cases are tabulated in paper 3187, and numerical examples are given; some of the latter are illustrated in Fig. 2 which applies to a shunt modulator using rectifiers which have a back resistance of 50 kilohms and a forward resistance of 250 ohms, the load termination being 1200 ohms at the wanted sideband frequency $(\omega_p + \omega_q)$. It can be seen that the dependence on signal-source impedance is often very great.

621.376.223
621.376.234

Field suppression of turbo-alternators

A brief article based on a Supply Section paper (3161) with the above title by J. R. Hill, B.Sc.(Eng.), A. Hunt, B.Sc.(Eng.), W. J. Joyce, B.Sc., and D. H. Tompsett, B.Sc.(Eng.), Associate Members. The paper was published individually in November 1959 and will be republished in Part A of the Proceedings. It was read at Savoy Place on the 9th December 1959 before the Supply Section (see p. 194). The authors are with the English Electric Co. Ltd.

If a fault develops in an alternator its stator circuit-breaker disconnects the machine from the system, but in addition to minimize damage the field must be removed and the stored magnetic energy dissipated harmlessly as quickly as possible.

General practice is to connect a resistor across the rotor slip-rings while disconnecting the exciter by opening the field circuit-breaker as shown in Fig. 1. The main requirements are:

Rapid transference of rotor current from the exciter circuit to the discharge resistor
Rapid decay of current in the discharge-resistor circuit
Limitation of the voltage across the rotor to a safe value.

A compromise between these has to be made.

Rotor current following 3-phase stator short-circuit

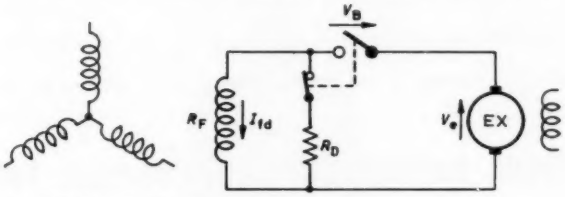
The form of the rotor current is shown in Fig. 2, the d.c. component rising to a peak usually 3–4 times the m.c.r. excitation. Superimposed is a fundamental-frequency a.c. component of peak-to-peak value about half that of the d.c. component. The d.c. and a.c. components both decay roughly exponentially with time-constants dependent on the alternator short-circuit time-constants and on the discharge resistance.

Normally the field circuit-breaker opens about 5 cycles after the fault and before the field current has decayed appreciably.

In the paper, expressions for the rotor current, the circuit-breaker arcing time, the peak rotor voltage, and a function representing the fault damage are given and the influence of various parameters on these quantities is examined. Comparison with test results indicates that inaccuracies occur owing to neglecting saturation and making some simplifying approximations.

Rotor-circuit voltage, circuit-breaker arcing time and discharge resistance

The rotor-circuit voltage is the product of the discharge resistance and the resistor current. At the moment of clearance the field circuit-breaker must be able to develop an arc voltage



1 *Field-suppression circuit*
$K = R_D/R_F$

V_B at least equal to the rotor voltage $I_D R_D$ plus the exciter voltage V_e.

If R_D is low enough the circuit-breaker will clear before it develops its full arc voltage. Normally it does so at a current trough (i.e. the a.c. component assists the circuit-breaker to clear) and the peak rotor voltage occurs at the next positive peak of the a.c. component.

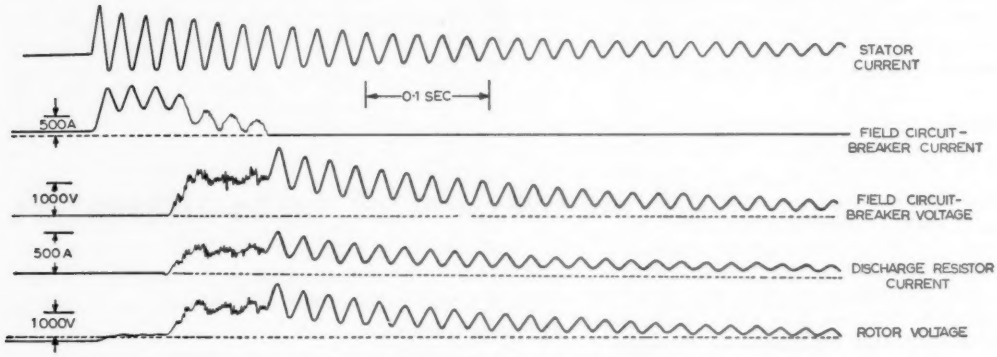
After circuit-breaker clearance the rotor current decays with a time-constant approximately $\tau_d'/(K + 1)$, and a high K appears desirable to accelerate the current decay. However, as R_D increases, the circuit-breaker arcing time becomes prolonged, limiting the rotor voltage until the decrement of the rotor current has reduced the rotor voltage appreciably. The rapid current decay apparently obtainable with high K is not realized, as the arcing time is increased allowing the current to persist in the exciter circuit.

For machines of 100–300 MVA rating the limitation of

rotor voltage to say 3kV and circuit-breaker arcing time to 0·06sec usually results in $K = 1·5–1·0$, higher values being permissible with smaller machines.

Stator damage

To compare the effectiveness of field suppression it is assumed that the core-plate damage is proportional to the time integral of the current into the fault.



2 *Oscillogram of field suppression of turbo-alternator when short-circuited*

The total fault energy is the sum of that fed in from the system, that supplied by the alternator before field suppression begins, and that supplied during field suppression.

Only the last is influenced by the field-suppression process.

The paper considers a 3-phase fault at the alternator terminals and derives an expression for $\int_0^t |I| \mathrm{d}t$. It appears that the damage is not greatly affected by K so long as K exceeds 2. With K decreasing between 2 and 1 some increase in damage may occur but, especially on large alternators, this slight hazard must be accepted.

Testing the field-suppression circuit-breaker

It is obviously undesirable to subject an alternator to several full-voltage short-circuits merely to test its field-suppression circuit-breaker, and synthetic d.c. test circuits cannot properly represent service conditions. The relevant circuit-breaker characteristics—arc voltage, arcing time, rate of rise of arc voltage—could be determined by d.c. tests and an estimate made of the field-suppression requirements by methods such as those indicated in the paper. The circuit-breaker's suitability could then be judged.

Consideration is also given in the paper to the discharge-contact duty and other, more complicated, field-suppression circuits.

621.313.322–81:621.316.91

New valves for submarine telephone repeaters

A brief account of an Electronics and Communications Section paper (3163) entitled 'Post Office valves for deep-water submarine telephone repeaters' by M. F. Holmes, B.Sc., and F. H. Reynolds, B.Sc.(Eng.), Associate Member. The paper is published this month in Part B of the Proceedings. The authors are at the Post Office Research Station.

Since the end of the Second World War the British Post Office has been actively interested in the insertion of submerged repeaters in submarine telephone cables. The development of these repeaters has required the provision of specially designed thermionic valves involving a considerable research effort, the first phase of which culminated in the design and production of the type6P12 valve used in the Newfoundland—Nova Scotia section of the first transatlantic telephone cable.

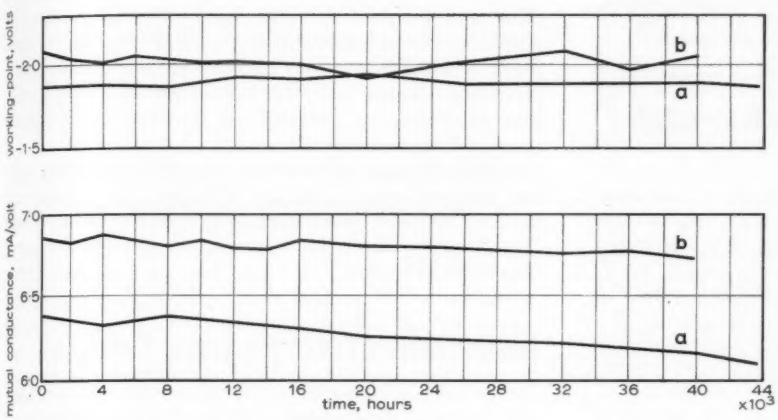
The second phase was initiated when it was realized that deep-water repeaters for transoceanic cables needed new valves. Such valves would provide a further improvement in the long-term stability of some of the principal valve parameters, a lowering of h.t. requirements without loss of output power, protection against breakdown of heater-cathode insulation and elimination of effects associated with the deposition of conducting films on the valve insulators.

The authorization of the CANTAT cable between Canada and the United Kingdom lent urgency to the completion of this second phase. The new valves known as the types 10P1 and 10P2 (for output and input stages respectively) are now available and are being used for the CANTAT cable and for a cable between the United Kingdom and Sweden. Some details of design and development are presented here.

Cathode material

The cathode-core material of a submerged repeater valve has a profound bearing on valve life through the influence it exerts on the growth of interface resistance. The tungsten-nickel core of the type10P valve marks a departure from the platinum core adopted for earlier types. A 40000h life test (Fig. 1) has clearly demonstrated that the trend of mutual

conductance has not been impaired by the change, nor has the long-term stability of the working-point. On the other hand the alloy cathodes are stronger mechanically and easier to activate. Both these factors tend to reduce the shrinkage rates in production.



1 *Life stability of mutual conductance and working-point*
a Platinum cathode core b Tungsten–nickel cathode core

Grid emission is avoided by using graphite-coated fins fitted to the control-grid support rods. These reduce the grid-wire operating temperature to below 240°C, where grid emission is negligible. Breakdown of heater–cathode insulation is prevented by using a ceramic sleeve between the heater and the cathode core. Growth of inter-electrode capacitances, of leakage and of leakage noise are all probably associated with the deposition of conducting films on the valve micas. These effects are reduced by the adoption of shields which protect vital areas of the insulating surfaces from direct evaporation.

H.T. restrictions

The basic design problems of the new valves centre on the h.t. restrictions which the valves must tolerate. The triode section must be designed to produce a specified anode current, working-point and mutual conductance within a limited screen-grid voltage and current. The following symbolic equation explains the balance which must be satisfied:

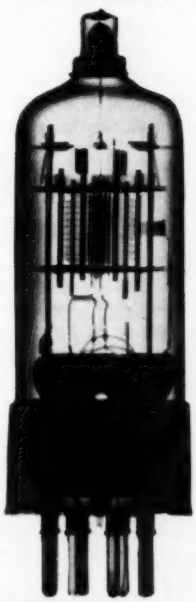
$$\left[\begin{matrix}\text{potential of}\\ \text{screen}\\ \text{grid}\end{matrix}\right] + \left[\frac{1}{\begin{matrix}\text{mechanical}\\ \text{quality}\end{matrix}}\right] = \left[\begin{matrix}\text{mutual}\\ \text{conductance}\end{matrix}\right] + \left[\begin{matrix}\text{magnitude}\\ \text{of working-}\\ \text{point}\end{matrix}\right] + \left[\begin{matrix}\text{steady}\\ \text{anode}\\ \text{current}\end{matrix}\right]$$

The criterion of mechanical quality in this context is partly the size of the inter-electrode gaps and partly the diameter of the grid wires. Any increase in one of the quantities on the right-hand side can be obtained only at the expense of at least one of the other two if the mechanical quality and screen-grid potential are defined as constants. A maximum screen-grid potential of 70 volts is permitted for the type10P valves and this is in the nature of a credit which has been fairly distributed between electrical performance and mechanical quality.

The shape and position of the knee in the anode characteristic is determined by suppressor-section design. Maximum undistorted output power must be associated with adequate secondary-emission suppression, high anode impedance and minimum anode-to-grid capacitance. The problem is complicated by the fact that low electron velocities and high anode currents produce inherent oversuppression. The best possible compromise has been adopted in the type10P1 valve to give an output of 200mW in conditions of optimum load.

Fig. 2 is an X-ray photograph of the kind obtained for the examination of type 10P valves.

It is considered that the type10P valves represent an advance in the development of submerged-repeater valves. Complete assessment must await the passage of time, and continued vigilance may point the way to further refinements in both design and manufacturing technique.



2 *X-ray photograph of a type 10P valve*

621.385.3 : 621.395.64

Synopses of papers

THE following are synopses of papers published in the *Proceedings* which have not been read at Institution meetings and which have not been reviewed in the *Journal*. They are included here primarily for reference. The papers have not been published individually, as have those for reading at meetings, but reprints will be available in due course

Amplitude and phase in v.h.f.–u.h.f. band

A synopsis of an Electronics and Communications Section paper (3155) entitled 'A method of amplitude and phase measurement in the v.h.f.–u.h.f. band' by G. D. Monteath, B.Sc., A.Inst.P., D. J. Whythe, B.Sc.(Eng.), Associate Members, and K. W. T. Hughes, B.Sc. The paper is published this month in Part B of the Proceedings. Mr. Monteath and Dr. Whythe are, and Mr. Hughes was formerly, with the British Broadcasting Corporation. Mr. Hughes is now with Racal Engineering Ltd.

A NULL method has been devised for measuring changes in the amplitude and phase of the transmission characteristic of a network at any frequency in the range 41–1000 Mc/s. A commercial instrument designed for admittance measurement is used with only slight modification for this application. Its subsequent use as an admittance meter is unaffected.

The measurement of phase can be made to within about $\pm 3°$, unless a large variation of amplitude is encountered, when reading accuracy limits the accuracy of phase measurement in the regions of small amplitude. If the error in a measurement is regarded as a vector, then with any amplitude variation the maximum value of the magnitude of this error vector is about 6% of the full-scale reading of the instrument.

621.317.34.029.6

Propagation of h.f. radio waves to long distances

A synopsis of an Electronics and Communications Section paper (3156) with the above title by F. Kift, Associate Member. The paper is published this month in Part B of the Proceedings. The author is at the Radio Research Station.

THE parabolic-layer transmission equation of Appleton and Beynon has been solved for a wide range of its main parameters. The author describes a method of applying the equation to any long-distance circuit, in which the successive hop lengths of each transmitted ray are adjusted to accord with ionospheric variations along the path.

The only data required are directly obtainable from published ionospheric predictions. The results are displayed on mode plots which comprise (a) a mode-angle plot showing the angles of elevation of all rays and the modes in which they are propagated to all points along a great circle of any extent, and (b) a mode-delay plot showing the time of travel of all rays instead of their angles of elevation.

The effect on the mode plots of diurnal and longer-term changes in the ionosphere is discussed. Two long paths are examined experimentally and it is shown that the number of signal components observed, their relative time-delays, their angles of elevation and their response to varying ionospheric conditions, all agree well with those determined theoretically from the mode plots, provided that the effect of the tropical sporadic-E layer is included.

Mode-angle plots may also be used without modification to find both the angular spectrum of back-scatter patterns and the most probable paths taken by atmospheric noise energy arriving at a receiver. Mode-delay plots also provide direct back-scatter patterns. 621.391.812.63

Distortion of single-tone f.m.

A synopsis of an Electronics and Communications Section paper (3182) entitled 'Fundamental and harmonic distortion of waves frequency-modulated with a single tone' by R. G. Medhurst, B.Sc. The paper is published this month in Part B of the Proceedings. The author is in the Research Laboratories of the General Electric Co. Ltd.

THE distortion of single-tone frequency modulation by passive networks whose amplitude and phase characteristics are non-linear with frequency is considered in some detail. A new approximate formula has been developed by extension of earlier methods, and its use, supplemented by the quasi-stationary approximation and by direct Fourier analysis, permits evaluation of distortion levels over ranges of parameters previously excluded.

The author gives a number of examples, comparison being made where possible with results obtained by other methods. Particular attention is given to distortion of the amplitude and phase of the fundamental, this being of importance in connection with television baseband requirements.

An attempt is made to clarify certain theoretical aspects, such as the validity of the quasi-stationary solution, which have been the subject of controversy. 621.376.3

A.C. operation of ion chambers at high fluxes

A synposis of a Measurement and Control Section paper (3207) with the above title by J. Watson, B.Sc., S.M., Ph.D., Graduate. The paper is published this month in Part B of the Proceedings. The author is with Ericsson Telephones Ltd.

WHEN a sinusoidally varying p.d. is applied between the electrodes of an ion chamber subject to ionizing radiations, the motion of the charge carriers and the form of the current in the external circuit depend on the applied voltage and frequency, the gas filling and the flux level.

The author examines such conditions, neglecting space-charge effects, and then modifies his analysis semi-empirically to take account of space-charge phenomena. A definition of 'saturation' as applied to chambers using alternating polarizing voltages is proposed, and experiments are described showing how variations in the above parameters affect this condition. Throughout the tests a standard A.E.R.E. RC1 ion chamber was used and was irradiated in the reactors Gleep and Bepo.

621.387.422 : 621.317.79

Impedance/frequency characteristics of glow-discharge reference tubes

A synopsis of an Electronics and Communications Section paper (3175) with the above title by F. A. Benson, D.Eng., Ph.D., Associate Member, and P. M. Chalmers, B.Eng., Graduate. The paper is published this month in Part B of the Proceedings. The authors are in the Department of Electrical Engineering, University of Sheffield.

The impedance/frequency characteristics of some cold-cathode glow-discharge tubes over the frequency range 300c/s–5Mc/s have been obtained. The results are shown to agree with an extended form of a theory by van Geel.

Impedance measurements indicate that there are several delayed effects in the glow discharge which affect the low-frequency impedance characteristics considerably. Tentative suggestions about the origin of these effects are discussed and the influence of some tube parameters on the magnitudes of the consequent delay times are indicated. The equivalent circuit of the glow-discharge tube is determined from the results.

621.387 : 621.316.722

Reignition voltages of freely recovering arcs

A synopsis of a Supply Section paper (3185) entitled 'The reignition-voltage characteristics of freely recovering arcs' by F. W. Crawford and H. Edels, B.Sc.Tech., Ph.D., Associate Member. The paper will be published in Part A of the Proceedings. Mr. Crawford is in the Electrical Engineering Department, Birmingham College of Advanced Technology, and Dr. Edels in the Electrical Engineering Department, University of Liverpool.

Advances in the knowledge of arc interruption have been achieved by simplifying the arc and its interruption condition and studying the recovery of the arc free from the presence of restriking voltage. The arc investigated is a d.c. pulsed discharge of about 100millisec duration burning freely between carbon electrodes. The reignition voltage of the arc at a given time after sudden interruption is obtained by pulsing with a unit function voltage. By varying the voltage a 50% reignition value is found, and by repeating at different delay times after interruption full reignition characteristics have been obtained to an accuracy within ±5%.

Characteristics are given for 10–50amp arcs in air, nitrogen, argon and hydrogen at pressures from 100 to 750mmHg and with gap separations of 1–5mm.

The results show that full recovery takes about 1sec and that breakdown occurs in different forms. For delays of 0–100microsec thermal breakdown occurs owing to the low resistivity of the decaying arc column and electrode regions. From about 0·1 to 1sec true spark breakdown is observed. At intermediate times the breakdown is affected by both free charge and reduced gas density.

621.387 : 621.316.57

Ferroresonant systems of circuit logic

A synopsis of a Measurement and Control Section paper (3167) with the above title by Prof. J. G. Santesmases, M. Alique, Dr.Sc., and J. L. Lloret, Bs.Sc. The paper is published this month in Part B of the Proceedings. Prof. Santesmases is Director of, and Señores Alique and Lloret are at, the Instituto de Electricidad y Automática, Madrid, Spain.

The authors describe the logical behaviour of a basic ferroresonant circuit, including a procedure for obtaining the 'and' and 'or' fundamental circuits through ferroresonant elements. The possibility of coupling these fundamental circuits allows the development of a ferroresonant system of circuit logic. A ferroresonant inhibit circuit and the simplification it permits in the logical system are studied.

621.374.32 : 681.142

Reversed lag for on-off temperature control

A synopsis of a Measurement and Control Section paper (3190) entitled 'The principle of reversed lag applied to on-off temperature control' by H. Sutcliffe, M.A., Associate Member. The paper is published this month in Part B of the Proceedings. The author is in the Department of Electrical Engineering, University of Bristol.

The author discusses cyclic fluctuations of temperature in an enclosure with a simple on-off control system. He shows that such a system can be improved by using two control elements completely immersed in the fluid of the enclosure and therefore not subject to datum error. The output signal of one of the control elements is required to have a lagging phase angle, and a theoretical analysis is made in which the thermal frequency responses of various configurations are compared. The author examines the relative merits of different configurations and describes the application of the theoretical principles to an experimental temperature-controlled enclosure.

621.316.74

CORRESPONDENCE

PERFORMANCES OF ELECTRIC LOCOMOTIVES OF THE FRENCH NATIONAL RAILWAYS

I WOULD like to reply to points made by Mr. H. Charnley (January 1960 *Journal*, p. 13) arising from my article in the November 1959 issue. He notices that during the high-speed tests on the 28th and 29th March 1955 the BB 9004 locomotive actually absorbed a power of 9400kW at the pantograph while the CC 7107 locomotive, which was heavier and was pulling the same coaches, absorbed only 8200kW.

These apparently discordant results were the outcome of an accident which occurred to the rear pantograph of the BB 9004 locomotive during the tests. In order to reach the maximum speed in the zone authorized by the technical services of the French National Railways it was necessary to employ a greater acceleration with this locomotive than with the CC 7107. With the BB 9004 locomotive the speed range from 174 to 205·7m.p.h. was covered over a distance of 5·4 miles whereas with the other locomotive the same increase in speed was reached over 6·5 miles.

The degree of field weakening of the motors is 75% (i.e. 25% of the field) on the CC 7107 and 40% (60% of the field) on the BB 9004.

The locomotives belonging to series 9400 have a brake horse-power of 3000 and weigh only 60 tons. On the motors, field weakening of 70% is carried out (30% of field). With the arrangements used on these machines, adhesion coefficients are obtained which are better than those of the preceding series. These new ideas are applied by our designers.

As regards the effort at high speed, electrical engineering shows that one obtains a greater effort by shunting than by varying the voltage. This is why shunting has also been used on single-phase locomotives.

Up to the present time we had not thought of the *Facel Vega* but since hearing from Mr. Charnley we are going into the matter!

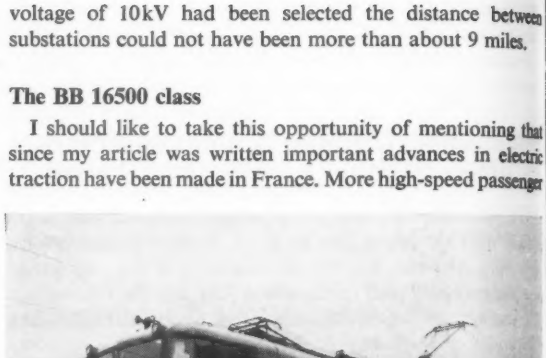
Concerning overheating problems, I would mention that in service we have found that the armatures showed heating up to 145°C and even to 160°C in motors with class H insulation. On the BB 16500 locomotives the motor windings are insulated according to class H, and with the motors of the BB 12000 locomotives in operation since 1954 class F insulation is employed.

Mr. Charnley comments on the choice of 25kV for the traction system adopted in France and England and standardized on an international level (U.I.C.). Calculations show that it is wise to use the highest possible figure. However, since insulation problems also have to be taken into consideration, particularly in tunnels, it has been necessary to reach a compromise, and the limit was finally set at 25kV.

In this way it is possible to allow for distances between substations reaching sometimes as much as 37 miles. If a voltage of 10kV had been selected the distance between substations could not have been more than about 9 miles.

The BB 16500 class

I should like to take this opportunity of mentioning that since my article was written important advances in electric traction have been made in France. More high-speed passenger trains are in service, including the *Aquilon* which does the same journey as the *Mistral* at an average speed of 75·5m.p.h.



A *Locomotive type BB 16500*
3452h.p.
Maximum speeds in service 55·9 and 93·5m.p.h.

Nearly 50 BB 16500-class locomotives are now in service and 115 are on order. The traction capabilities of the BB 12000-class locomotive are so great that they exceed what is required for the haulage of a large number of trains, and it was for this reason that a new type of light BB locomotive, the 16500, was designed. It weighs 67 long tons, has a continuous rating of 3500h.p. and is equipped also with ignitron rectifiers (Fig. A).

This type is the most economical of the electric mixed-traffic locomotives, owing to a variety of technical innovations, and is a very unusual engine. As far as we are aware there is no similar locomotive elsewhere in the world: a new formula has been found.

Our research led, for the first time, to the manufacture in quantity of bogies with only one traction motor and the use of a double-ratio gear mechanism by means of which the characteristics of the locomotive can be changed in a few minutes, transforming it from a goods locomotive into a fast passenger engine. For goods traffic the maximum speed is 56m.p.h., and for passenger traffic 93·5m.p.h.

The improvement in adhesion anticipated from the coupling

of the axles had already been realized during tests with a BB 12000 locomotive the axles of which had been mechanically coupled. The general results obtained by MM. Bernard and Guillier during adhesion tests carried out on several BB 16500 locomotives, without sanding, on straight and curved tracks and on dry, wet and greasy rails show that a mean curve starts from about 0·36 for standstill, decreases to 0·30 for a speed of 6·2 m.p.h. and is still at 0·29 for 31 m.p.h. The best values remain at about 0·40 for a speed of 25 m.p.h.

The adhesion results obtained with the BB 16500 locomotive with single-motor bogies seem to be 20% higher than those obtained with the BB 12000 locomotive, particularly at the higher speeds.

The traction programme laid down for the BB 16500 locomotives was as follows:

goods (ordinary stock)	2450 long tons on a gradient of 1 in 200
	1801 long tons on a gradient of 1 in 125
	1501 long tons on a gradient of 1 in 100
passenger	787 long tons on the level at 82·5 m.p.h.

As for passenger trains hauled by a BB 16500, we would cite the journey Paris–Lille, made non-stop in 1 h 58 min, with a train of 13 carriages weighing 596 long tons, in each direction, i.e. at an average speed of 79 m.p.h.

This locomotive is well suited to any kind of traffic, even suburban. At present the lines in the northern suburbs of Paris electrified to use 50 c/s single-phase current are served by standard train-sets of eight carriages either pushed or pulled by BB 16500 locomotives at 62 m.p.h.

F. NOUVION

Société Nationale des Chemins de Fer Français
Direction du matériel et de la traction
Division des études de traction électrique
41 boulevard de la Gare
Paris XIII[e]

23rd January 1960

I HAD written to comment on Mr. Charnley's letter in the January 1960 *Journal*, but the Editor has kindly shown me M. Nouvion's letter and to avoid duplication I would only add the following.

It was possible to change over without accident the defective pantograph in the BB locomotive at high speed while accelerating, as the pantograph and contact wire were continuously watched by an engineer at a viewing point in the first carriage of the train. He was in telephonic communication with the driver. Otherwise the damage would not have been discovered until the pantograph and contact wire had been destroyed.

It is interesting to note that, in the first part of the deceleration while the speed was too high to apply the wheel brakes, braking was obtained by opening all the train windows. This would seem a good argument for permanently closed windows with some kind of air-conditioning in high-speed trains.

Mr. Charnley misses the point of 50 c/s traction when he advocates a lower contact-wire voltage. The big saving in cost of the distribution system, substations and overhead catenary can be realized only when the highest practical contact-wire voltage is employed, the more so as the higher frequency increases the voltage drop compared to the former 25 and 16⅔ c/s systems.

Mr. Charnley's idea of suppressing the locomotive transformer is practicable only on phase-convertor locomotives. Unfortunately the rectifier locomotive has much better and more flexible characteristics and is also cheaper to build so that this idea is unlikely to find much interest.

I hope M. Nouvion will pardon these remarks from an old *stagiaire* of the Paris–Orléans–Midi Railway.

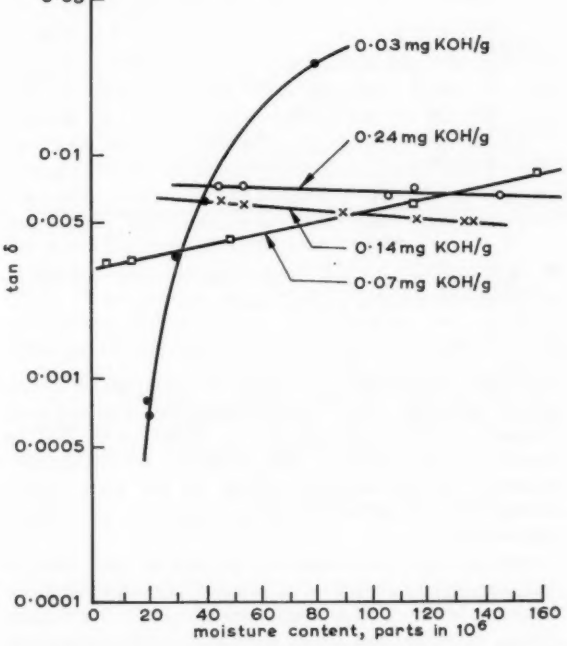
F. V. G. BIRD, ASSOCIATE MEMBER

c/o American Express Co.
Bahnhofstrasse 20
Zürich 1, Switzerland

11th February 1960

THE ANOMALOUS EFFECT OF MOISTURE ON THE ELECTRICAL PROPERTIES OF PETROLEUM OIL

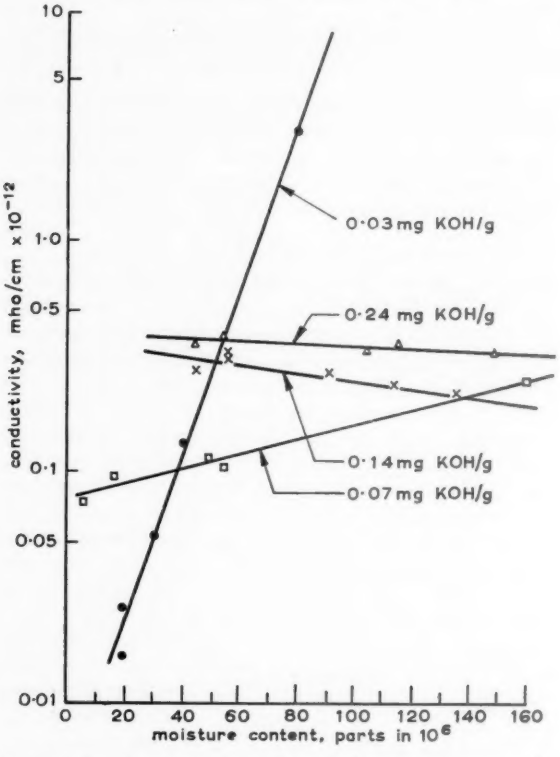
IT is well established that the presence of water in oil influences its electrical properties and it has been generally accepted that these properties deteriorate with increase in moisture content.



1 *Relation between loss tangent and moisture content of transformer oils of various acidities*

However, a condition of an oil found to have an anomalous effect on the changes in electrical properties caused by the addition of moisture was the degree of oxidation, and as this state was readily controllable it was decided to investigate this effect in some detail.

Several samples, each about 2 litres, of a new transformer oil were placed in Winchester bottles and subjected to a temperature of 115°C for various periods of from 1 week to 3 months, the samples being saturated with dry air once



2 *Relation between conductivity and moisture content for transformer oils of various acidities*

every 24h. Sheet copper was added, to give 1 cm² of copper surface per millilitre of oil, to accelerate this oxidation. After completion of the heat ageing, the acidity of the oil was measured by titration, the copper, if present, by a photometric method[1] and the moisture present by the Karl Fischer technique[2] (due allowance being made for any copper present).

Moisture was then added to the oils at each stage of oxidation to give a range of moisture content between 10 and 110 parts in 10^6. This was achieved by adding the requisite volume of water from a micropipette to a 200ml sample of oil and then vigorously agitating after heating to 90°C for two hours to disperse the moisture through the oil. This was followed by a check of the moisture content.

Measurements

Measurements of loss tangent and conductivity were made, in that order, on a 50ml sample of each oil in a Henley oil test cell. A Schering bridge at 1kV 50c/s was employed for loss-tangent measurements and an electronic megohmmeter with a maximum calibration of 20×10^{12} ohms, at a direct voltage of 500, for conductivity measurements.

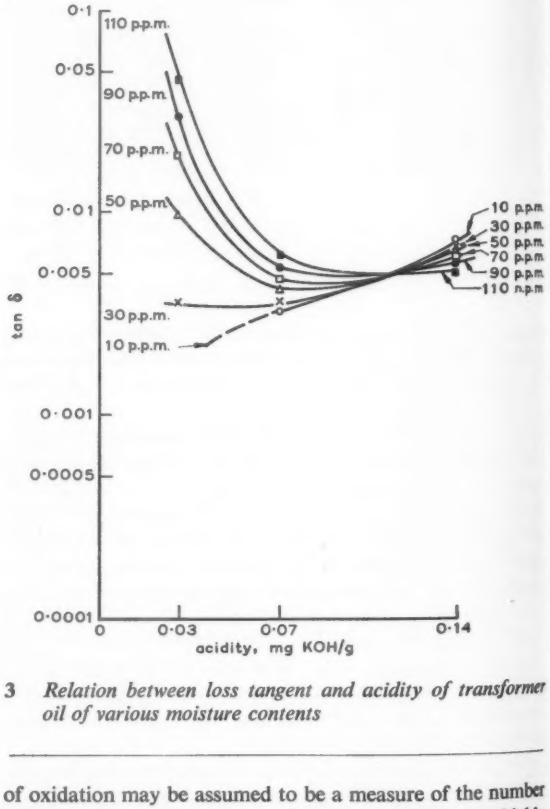
The effects on the oxidized oils of various quantities of added moisture are illustrated in Figs. 1–4.

It is evident from Figs. 1 and 2 that, as the degree of oxidation of an oil increases, the addition of moisture has a decreasing effect on its electrical properties (i.e. the slopes of the conductivity/moisture curves and the loss-tangent/moisture curves decrease). Further, at certain degrees of oxidation the sign of the slope is reversed and the addition of moisture is actually producing an improvement in the electrical properties of the oil.

This is shown even more clearly if the electrical properties of the various oils are plotted as a function of acidity as in Figs. 3 and 4, whence it can be seen that at a certain acidity there is a complete reversal in the moisture-content/electrical-characteristic relation beyond which the higher-moisture-content oils have the superior electrical properties.

Explanation

A tentative explanation for this phenomenon is offered as follows. The acid values quoted as representative of the degree

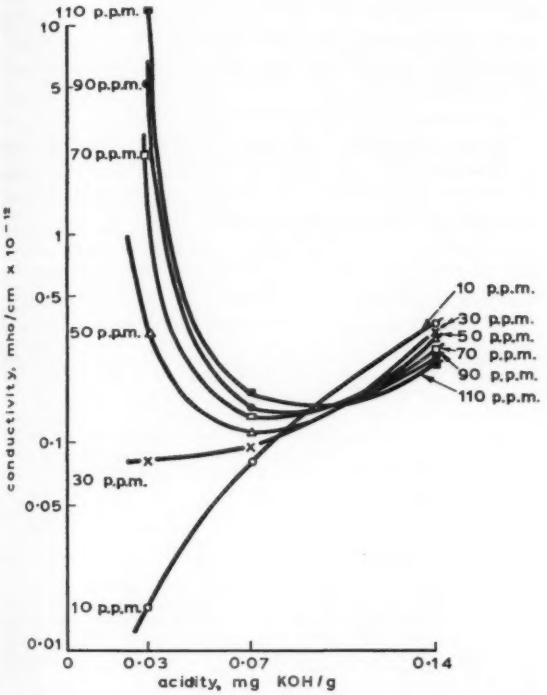


3 *Relation between loss tangent and acidity of transformer oil of various moisture contents*

of oxidation may be assumed to be a measure of the number of carboxyl groups present. Moisture added to a highly oxidized oil may very well attach itself to these acidic groups by means of a hydrogen bond, in which case the water may be

prevented from ionizing or the mobility of the resultant ion may be greatly reduced.

This could explain the lack of a marked change in conductivity on the addition of moisture to these highly oxidized oils; however, the distinct improvement observed could be due to moisture being an agent either in the formation of molecular complexes of increasing size, which would therefore be less mobile, or in a charge-neutralization process. In either case



4 *Relation between conductivity and acidity of transformer oil of various moisture contents*

the water molecule could act as a complexing agent by means of hydrogen bonding.

The observed change in conductivity appears to account to a large extent for the similar change in tan δ (i.e. $G/\omega C$ is of the same order as the measured tan δ). However, it is felt that the following mechanism may account for a proportion of the change in tan δ. If we consider an oxidized naphthalene type of symmetrical hydrocarbon structure as follows: it is known that the introduction of a polar group in position 1, for example, will change the dipole moment of the molecule from zero to a definite quantity, but if a similar group is also attached in a symmetrical position (i.e. position 5) the moment is again reduced to zero.

It would follow that if pairs of symmetrically placed groups or all of such groups take up a water molecule, symmetry may not be disturbed and therefore no deterioration in electrical properties will take place with the addition of moisture. Furthermore a symmetrically oxidized oil molecule which has procured a dipole moment by the attachment of an odd number of water molecules to form an unsymmetrical structure could have its moment reduced by the addition of one or more further water molecules, and this could result in an improvement in tan δ.

The above ionic and polar explanations may very well be interrelated in that the formation of symmetrical structures may be a step in the formation of charge-neutralizing complexes.

A second series of experiments on oils oxidized without the addition of copper resulted in precisely the same phenomena.

To investigate these theories further it is intended to examine the effect of moisture on the electrical characteristics of various simple oxidized organic molecules.

F. B. WADDINGTON, B.SC., and J. HEIGHES
Research Department
Associated Electrical Industries (Manchester) Ltd.
Trafford Park
Manchester 17

27th January 1960

1 THOMPSON, C. N.: *Journal of the Institute of Petroleum*, 1958, **44**, No. 417, p. 295

2 WADDINGTON, F. B.: *Laboratory Practice*, 1959, **8**, No. 8, p. 275

FIRST PRINCIPLES

I ALWAYS remember a saying of the late Mr. J. S. Peck who was for many years the Chief Engineer of what was until recently the firm of Metropolitan-Vickers. He was asked about the university education of engineers and said that he thought the subject in which they should specialize was 'first principles'. There is a great deal of truth in this, but, if it is carried to a logical conclusion, engineers in universities would learn nothing but mathematics and physics.

There is bound to be a certain amount of specialization in engineering education, and a professor of electrical engineering has a very difficult task in deciding how much. I do not think too much stress can be laid on the desirability of giving instruction about how the first principles are applied, by numerical calculation. It is the application of first principles 'for the use and convenience of man' that is the function of the engineer, and this should never be forgotten.

E. W. MARCHANT, D.SC., F.C.G.I.,
PAST-PRESIDENT, HONORARY MEMBER
Brook Farm
Grendon
Atherstone, Warwickshire

4th February 1960

THE CROSSED-CYLINDER SPARK-GAP AS A PEAK VOLTMETER

IT is frequently necessary to measure the peak value of a high voltage existing in a piece of apparatus when a suitable voltmeter is not available, for example at a remote site where resources are limited or in a low-energy piece of equipment where a very-high-impedance voltmeter would be required. In such conditions the sphere-gap used in accordance with

B.S. 358 (now under revision by the I.E.C.) has been recommended.

In my experience it has been found that even when spheres of adequate size and quality have been available large errors have been introduced into such measurements by the lack of sufficient skill in setting up the sphere-gap; for this reason the crossed-cylinder gap, which is much simpler to construct and set accurately, has been investigated with a view to determining its limitations as an alternative to the sphere-gap.

In order to minimize the labour consistent with a sufficiently exhaustive investigation of the characteristics of the crossed-cylinder gap, only one size of cylinder diameter, namely 6·25cm, has been used. In particular the effects were noted of:

(a) cylinder length in the range 3–7 diameters
(b) deviations from the perpendicular in the disposition of the cylinders with respect to one another, and
(c) shape of the cylinder ends.

Test results

The following results were obtained for breakdown voltage, measured in kilovolts (peak):

spacing	6·25cm-dia. spheres			12·5cm-dia. spheres		6·25cm-dia. cylinders set at 90° one to the other			
	present tests	B.S. 358	I.E.C. proposal	B.S. 358	I.E.C. proposal	7 dia. long	5 dia. long	4 dia. long	3 dia. long
cm									
0·5	17·2		17·2	16·7	16·8	17·2	17·0	17·1	17·0
1·0	31·6	31·9	31·9	31·5	31·7	31·5	31·5	31·3	31·1
1·5	45·6		45·5	45·5	45·5	45·5	45·5	45·2	45·1
2·0	59·0	58·2	58·5	59·4	59	59·4	59·4	59·0	58·4
2·5	71·1	69·6	69·8	72·6	72·5	72·6	72·3	71·9	71·9
3·0	80·9	79·1	79·5	85·4	85	85·1	85·3	85·1	85·1
3·5	88·9	87·5	87·5	97·7	97	98·4	98·3	96·7	
4·0	95·5	94·8	95	110	108	111·4	111·0	110·3	
4·5	101·0			121		123·6	120·7	120·0	
5·0	105·9			132	129	132·5			

The reduction in the breakdown voltage of the crossed-cylinder gap with the ends of the cylinders flat or with a radius was too small to measure, up to deviations of 30° from a right-angle at a spacing of 2cm.

Sparkover occurred at the ends of the cylinders when this sparkover path was about 3·5cm with a radius at the cylinder end or about 7cm with flat ends. This was the only instance in which the shape at the ends of the cylinders influenced the test results.

Conclusions

There is a small discrepancy between the breakdown voltages measured on the 6·25cm sphere-gap and those published in B.S. 358. These discrepancies however are of the same order as those existing between B.S. 358 and the I.E.C. proposed calibration, and give a measure of the accuracy of the sphere-gap.

The breakdown voltages measured on the longest cylinders agree well with those published in B.S. 358 for sphere-gaps having electrode diameters twice that of the cylinders. Except at the largest spacing the differences between the voltages measured for the cylinders and those given in the I.E.C. proposal are small.

It seems that a crossed-cylinder spark-gap may be used as a peak voltmeter, the calibration being taken as that for spheres of twice the cylinder diameter. The tolerance in positioning the electrodes appears to be far greater than that which is acceptable for spheres; it is not necessary for the mutual angle between the crossed cylinders to be exactly 90°, deviations of up to 30° introducing negligible errors. Furthermore it does not appear to be necessary to finish the ends of the cylinders in any particular manner.

The crossed-cylinder spark-gap is more convenient to set up than the sphere-gap (particularly if the high-voltage busbar can be used as one electrode) and may be employed as a peak voltmeter of at least equal accuracy.

The calibration of the crossed-cylinder gap was within an r.m.s. deviation of 0·85% from that of a sphere-gap of twice the diameter of the cylinders. The difference between the two calibrations could be attributed to experimental errors.

Acknowledgments

This work was carried out in the Cockcroft Laboratory of the College of Science and Technology, Manchester, under the direction of the writer as special visiting lecturer in high-voltage engineering.

Thanks are due to Prof. E. Bradshaw for provision of facilities in the laboratory, and to Sir Willis Jackson, Director of Research and Education, Associated Electrical Industries (Manchester) Ltd., for leave of absence from the Research Department to carry out the duties of special visiting lecturer. Thanks are also due to Mr. R. K. Pearson who as a student in the College made most of the measurements.

W. P. BAKER, B.SC., ASSOCIATE MEMBER

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Manchester 17

5th February 1960

OBITUARY

PHILIP RAY COURSEY

Philip Ray Coursey, B.SC.(ENG.), who died on the 3rd January 1960 was born in London on the 7th May 1892. He was educated at University College London and later became assistant to Sir Ambrose Fleming.

During the First World War he was Admiralty inspector of wireless telegraphy in H.M. Auxiliary Patrol and in 1918 became physicist at H.M. Signals School.

He did much to encourage the amateur-wireless movement. He served on the Council of the Wireless Society of London and in 1921 and 1922 took a leading part in organizing the amateur short-wave transatlantic tests. From 1919 to 1923 he collaborated with Prof. G. W. O. Howe on *Radio Review* as assistant editor. Later he acted as research editor of *Wireless World* until 1925.

In 1922 he became chief engineer of the Dubilier Condenser Co., a position which he held until 1931 when he was appointed technical director of the company. He retired in 1957 and became technical consultant to the company in addition to retaining his directorship.

He was the originator of many important developments and the inventor of numerous patents. His extensive knowledge and experience were a valuable contribution to the industries with which he was connected and he took a prominent part in, and made valuable contributions to, the deliberations of the electrical and telecommunication industries both on home and on international committees. He had a gift for teaching, and his books and many contributions to technical publications were a model of clear exposition. He could never tolerate inefficiency, but his kindly nature and patience demonstrated his character at its best when he could help others in their problems by sharing with them his wide technical knowledge and experience.

He is survived by his widow and a son.

He joined The Institution as a Student in 1910 and was elected an Associate Member in 1918 and a Member in 1926. He served as Honorary Assistant Secretary of the Students' Section in 1914–15 and as Honorary Secretary in 1915–16.

He was awarded a Student Premium jointly with G. G. Dawson in 1912 for their paper entitled 'An account of some experiments made with various wireless telegraphy transmitters and a complete description of an inexpensive apparatus for use over short distances' and a Wireless Premium jointly with S. N. Ray in 1939 for their paper on 'Electrolytic condensers'. These were published in the *Journal* together with others written in 1927, 1949 and 1950.

H. S. P.

ALBERT HENRY WEAVER MARSHALL

The death of Albert Henry Weaver Marshall on the 12th September 1959 at Clevedon, where he went to live on his retirement from the North Eastern Electricity Supply Co. in 1934, removes another of the few remaining pioneers of electricity supply. He was born on the 28th July 1873, the son of a farmer at Dundry, Somerset.

In 1891 he became a pupil for three years with the Bath Electric Lighting and Engineering Co., attending Merchant Venturers' College, Bristol, and passing with honours the City and Guilds examination. From Bath he went to R. Hornsby and Sons, Grantham, as a premium pupil in return for looking after the works arc lamps.

In 1896 he decided to try his luck in the United States but found trade so bad that he returned the following year. The boat called at Cork and quite by accident he found work with C. H. Merz who was then establishing for the British Thomson-Houston Co. a lighting and tramways system. He remained with the company constructing and commissioning cars at Sheffield Lane, then working on the equipment of the Central London Railway, of which when it opened he became 'acting locomotive superintendent'. He rejoined B.T.H. on tramway contracts and after a year as traction engineer for the Brush Co. joined Merz and McLellan in 1903 as resident engineer for the electrification of the Tynemouth suburban lines of the North Eastern Railway.

From 1905 he was closely associated with Merz and McLellan as chief engineer to the Cleveland and Durham Power Co. with headquarters in Middlesbrough. When the company was acquired by the Newcastle upon Tyne Electric Supply Co. in 1918, he was taken over with his staff and in 1924 was transferred to Newcastle.

In his retirement he served on the Clevedon Urban District Council, of which he became vice-chairman. When over 80 years of age he made a study of the steam engine, the results of which he embodied in an article in the August 1957 *Electrical Power Engineer*. He was interested in model-aeroplane construction in the early days of aviation development, and in the development of wireless, and also in photography, local history, archaeology and golf. He was predeceased by his wife in 1957 and is survived by three daughters.

He joined The Institution as an Associate Member in 1902 and was elected a Member in 1910. He served on the Newcastle local Centre Committee from 1911 to 1914, being vice-chairman from 1914 to 1916 and chairman in 1917–18. During this period he took the initiative in promoting District Meetings at Middlesbrough which led to the formation of the Tees-Side Sub-Centre in 1919. He served as a member of Council from 1920 to 1923 and on the North-Eastern Centre Committee from 1925 to 1928. J. R. B.

LEONARD ARTHUR CHARLES POOLEY

Leonard Arthur Charles Pooley who died in Southern Rhodesia on the 26th February 1959 was born in Kimberley, South Africa, on the 6th November 1902. He was educated at Christian Brothers College and at the School of Mines, Kimberley. After completing his engineering training at Faraday House and with C. A. Parsons he joined Merz and McLellan, consulting engineers, in 1925, leaving them in 1937 for an appointment as chief technical sales engineer of the power cable division of Standard Telephones and Cables.

He was mobilized with his Territorial Royal Engineers unit in 1939 and served in the North African campaign. Retiring with the rank of major in 1945 he returned to South Africa to take up an appointment with the South African Electricity Supply Commission. He subsequently joined the Faraday Engineering Co., Bulawayo, as chief engineer and was managing director of the company when it became merged with its principal associate in 1955. He then joined Merz and McLellan (Rhodesia) and took a prominent part in the Kariba project on which he was engaged at the time of his death.

'Leo' Pooley will be remembered by his many friends in England, which he revisited in 1952 and 1957, and in South Africa, as a man of convivial tastes and great personal charm who dearly loved mixing with his fellows, but whose massive frame seemed most at home in the open spaces to which, as an engineer, golfer and hill walker, he inclined.

He is survived by his widow, a son and a daughter.

He joined The Institution as a Student in 1921 and was elected an Associate Member in 1929 and a Member in 1940. R. C. M.

MAURICE HAZEL WHITEHOUSE

Maurice Hazel Whitehouse who died on the 12th December 1959 was born at Wolverhampton on the 14th January 1892. He was educated at the Higher Grade Secondary School, Wolverhampton, and then served a four-year apprenticeship with part-time study at Wolverhampton and at Birmingham municipal science and technical schools.

He commenced his career in the electricity supply industry on the technical staff of Wolverhampton Corporation Electricity Supply Department in 1911. He was eventually appointed senior distribution assistant in 1938, being responsible for the design, installation and maintenance of all high- and low-voltage distribution plant. He remained in this position until 1948 when the Midlands Electricity Board appointed him chief assistant commercial engineer with special duties in connection with commercial publicity and sales development on the staff of the Wolverhampton and District Sub-Area. During the whole period he rendered invaluable service to the industry.

He also used his expert photographic knowledge in compiling what amounted to a history of the development of the Wolverhampton undertaking, but it is chiefly for his personal attributes that he will be remembered by all those who were fortunate enough to be associated with him. He was always eager to place the benefit of his knowledge and experience gained throughout the years at the disposal of all those requiring advice.

He joined The Institution as a Student in 1912 and was elected an Associate Member in 1916 and a Member in 1943. F. J. E.

PAPERS AND MONOGRAPHS

published individually this month

Papers accepted for reading at meetings and monographs are first published individually and are republished later in the Proceedings of The Institution; as soon as the separates are available they are described in this feature. The papers are supplied free of charge; the price of a monograph is 2s.

In addition reprints of papers read at meetings including the discussions thereon and of papers not read at meetings become available, price 2s., within two months of their appearance in the Proceedings.

Applications quoting the serial number of the paper, monograph or reprint as well as the author's name and accompanied by a remittance where appropriate should be addressed to the Secretary of The Institution. For convenience, books of five vouchers for this purpose can be obtained in advance, price 10s.

Those who obtain a copy of a paper published individually are urged—if they do not take the Part of the Proceedings in which it will be republished—to apply in due course for a reprint as this is the final and correct version and includes the discussion.

PAPERS

V.H.F. sound broadcasting *Paper* 3221E, *Part B*

R. V. HARVEY, B.SC.

IN f.m. reception the delayed signals caused by multipath propagation result in unwanted amplitude and phase modulation of the primary signal and consequent distortion of the programme output of the receiver. The author describes the results of tests which were carried out in simulated multipath conditions to determine the importance of the parameters of both the received signal and the receiver in influencing the subjective annoyance caused by the distortion.

With a well designed receiver the distortion of piano music is 'slightly disturbing' when a single delayed signal is present having an equivalent path difference of 8 km and an amplitude of 35% relative to the primary signal. For a path difference of 29 km, however, the permissible relative amplitude is only 6% for the same subjective annoyance. In the same conditions the distortion of speech is imperceptible. In comparison, receivers providing inadequate suppression of the unwanted amplitude modulation are much more susceptible to the distortion.

The use of pre- and de-emphasis appreciably reduces the distortion, being equivalent to a reduction of about 8 dB in the amplitude of the delayed signal when the path difference is about 16 km. Similarly the distortion is less noticeable when the loudspeaker has a poor response at high audio frequencies.

The mechanism of multipath distortion is discussed, and the harmonic spectra of the distortion are shown for particular conditions.

To be read on the 4th April 1960

An experimental transistor-controlled component selection and testing machine *Paper* 3219M, *Part B*

T. C. CARDWELL, B.SC.(ENG.), J. R. W. SMITH, M.SC., *and* G. H. KING, B.SC.

THE authors show the need for a selection and testing machine in the light of recent developments in the automatic assembly of components onto printed-wiring boards. The advantages of a programmed machine are given and the flexibility and simplicity obtained are illustrated.

The general operation of the machine is outlined. Examples of the method of coding and the technique of programming onto punched-paper tape are included. The build-up of the electronic control from a number of relatively simple basic circuits is demonstrated.

The range of components handled, details of the test bridges, and the over-all speed and reliability are presented.

To be read on the 26th April 1960

Henri de France colour-television system *Paper* 3251E, *Part B*

R. CHASTE, ING.É.S.É., L. ÈS SC., *and* P. CASSAGNE, ING.É.S.N.T., L. ÈS SC.

THE authors present the work done by C.F.T. on the system of colour television of Henri de France. They define the objectives of the team of research workers responsible for the development. They consider the fundamental principles and special features of the system and describe the encoding and decoding units. The practical results and theoretical aspects of the ease of transmission of the coded signals are discussed.

To be read on the 27th April 1960

New form of crane-hoist control using a 3 : 1 pole-changing induction motor *Paper* 3226U, *Part A*

O. I. BUTLER, D.SC., *and* V. AHMAD, PH.D.

THE basic practical requirements of crane-hoist drives are summarized, and the latest developments, including closed-loop-control methods, in satisfying such needs with a.c. drives are discussed. In particular, the authors investigate the suitability of an economical design of a 3 : 1 pole-changing induction motor for crane-hoist drives.

In conjunction with a single-phase auto-transformer, the pole-changing motor enables the best use to be made of d.c. and a.c. dynamic braking, which further assists in lowering the energy dissipation in the motor circuits as well as reducing the number and size of the secondary-circuit resistors and contactors. The performance characteristics are such as to satisfy crane-hoist requirements without undue complexity in the complete equipment.

To be read next session

MONOGRAPHS

Characteristics of the trigatron spark-gap at very high voltages *Monograph* 364M

T. E. BROADBENT, M.SC., PH.D.

CURVES are given showing the working range and time-lag characteristics of a trigatron spark-gap working in air at voltages up to 1 MV. It is shown that, for voltages of this magnitude, a single-stage trigatron spark-gap of suitable design provides a simple and convenient method of chopping the voltage at any required instant. Factors which affect the performance of the gap are discussed.

Experimental study of the slot aerial and the three-element collinear array of slot aerials *Monograph* 365E

RONALD KING, PH.D., *and* GILBERT H. OWYANG, PH.D.

THE principle of complementarity is reviewed with particular reference to its application to the study of slot transmission lines and slot aerials. The conventional techniques for making measurements on transmission lines are shown to be applicable to a two-slot line that is used to centre-drive a slot aerial. The complementary normalized impedance of such an aerial as a function of its half-length, and the distributions of the electric and magnetic field along it, have been measured and are described.

The experimental results for the slot aerial are compared with the approximately complementary ones derived theoretically for a centre-driven cylindrical aerial. The effect of the finite thickness of the ground screen in which the slot line and aerial are cut is discussed. A similar study is explained for a three-element collinear array of slot aerials.

A theory of steady forces in variable-parameter networks *Monograph* 366M

W. E. SMITH, B.SC.

PASSIVE linear reciprocal networks with elements dependent on a generalized co-ordinate x are investigated in order to evaluate the steady component of the corresponding generalized force $(F_x)_{av}$. Methods are found for expressing this force in terms of parameters measurable at the input terminals of the network.

The analysis is particularly relevant to the absolute calibration of a class of square-law electrical measuring instruments, but the formalism is also applicable to other network systems where impedance is a useful concept.

Further theory of a certain continued fraction *Monograph* 367M

O. P. D. CUTTERIDGE, M.SC.(ENG.), PH.D.

THE author develops further theory of a certain type of continued fraction relevant to the problem of determining the character of the zeros of a polynomial. Two theorems provide tests for the number of positive zeros, for the number of real zeros and for the number of pairs of conjugate complex zeros of a real polynomial. Two numerical examples are included, one of which shows the application of the method to a problem in linear-network theory.

Flux distribution in a permeable sheet with a hole near an edge *Monograph* 368M

B. V. JAYAWANT, PH.D., B.ENG.

IN the measurement of the distribution of magnetic flux in the cores of electrical machines by locating search coils in them, the presence of a search coil will alter the flux in that region. It is therefore necessary to make a correction to the measured flux. The problem is the solution of Laplace's equation in two dimensions in a material assumed to be of constant permeability, and it has an analogy in hydrodynamics. The solution is obtained by a conformal transformation; the correction is quite significant when the distance of the centre of the hole from the edge is equal to its diameter.

Orthogonal codes *Monograph* 369E

H. F. HARMUTH, DIPL.-ING., DR.TECH.

CODE alphabets whose characters can be represented by a finite sequence of digits of value $+1$ or -1 have been extensively investigated. The characters of these binary codes may be considered to be superpositions of orthogonal functions, one for each digit, which are multiplied by $+1$ or -1. A character of an orthogonal code consists of one function of a set of orthogonal functions multiplied by $+1$ or -1.

ELECTRIC POWER IN EUROPE

THE rate of increase of electric power consumption in various European countries ranged between 5 and 20% for 1958 as compared with 1957, and it is forecast that this annual increase may reach an average of 9% by 1965 and 7·3% subsequently. The 1958 figure is higher than the rate of increase of industrial production, showing that electric power is being substituted for other forms of energy in many sectors.

This was one of the topics discussed at a meeting in Geneva of the Committee on Electric Power of the Economic Commission for Europe on the 27th–29th January 1960. Other subjects under consideration were the rationalization of the use of electric power and the covering of peak loads; an *ad hoc* committee was set up to make specific studies of the latter. Exchanges of information between European countries were also reviewed.

It was announced that the group of experts for the study of hydroelectric resources will provide a bulletin every six months giving monthly data for a limited number of important river basins in widely separated areas of Europe, and that the same group is about to publish a map of the gross potential hydroelectric resources of Europe.

In considering its programme of work for 1960–61, the Committee instructed the Secretariat to undertake a preliminary economic study on the subject of problems encountered in the construction and operation of electric power plant and in the transmission of the electric power produced. It recognized the desirability of studying methods of assessing economic efficiency due to the introduction of automation in electric power production plants, and decided to consider, at its next session in October 1960, specific economic problems relating to the construction and operation of thermal power plants which might warrant further study on its part.

The Committee expressed its gratitude to the Governments of France, the United Kingdom and Ireland, which had organized in 1959—and intended to organize again in 1960—a study tour for the experts of the working party for the study of rural electrification. It also noted with pleasure the invitation extended to it by the Romanian representative to make a study trip to Romania after the Committee's next session.

The session was attended by representatives from Austria, Belgium, the Byelorussian Soviet Socialist Republic, Czechoslovakia, Denmark, the Federal Republic of Germany, Finland, France, Greece, Hungary, Italy, the Netherlands, Poland, Romania, Spain, Sweden, Switzerland, the Ukrainian Soviet Socialist Republic, the Union of Soviet Socialist Republics, the United Kingdom, the United States, and Yugoslavia. Mr. R. Hochreutiner (Switzerland) and Mr. T. Dryzek (Poland) were re-elected Chairman and Vice-Chairman of the Committee, respectively.

New radiotelephony service

EQUIPMENT recently installed at the Lands End Post Office radio station provides three radiotelephone channels for a new service to passenger liners. Hitherto telephone communication between passengers on larger ships and United Kingdom subscribers has been restricted to the h.f. channels of the long-distance service even when within range of an m.f. coast station.

Initially the equipment will provide fully duplex working using amplitude-modulated double-sideband signals, but it can be operated on single sideband with full or reduced carrier. A new type of transmitting aerial has been installed which has a broadband characteristic over approximately the range of coast-station radiotelephony frequencies in the m.f. band.

All the radio- and audio-frequency apparatus is housed in an unattended outbuilding. A control panel at each telephony operating console in the main station enables the operator to control the channels and provides switching, monitoring and call-timing facilities.

The cost of a three-minute call has been reduced from 36s. to 10s. 6d., and similar equipment is shortly to be installed at Niton, North Foreland and Anglesey stations.

LIBRARY ACCESSIONS

**Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members*

BOOKS

BEER, S. 621–52

Cybernetics and management*

London: English Universities Press, 1959. pp. xviii, 214. 22 × 14cm. 25s.

This work on the science of communication and control is not intended for the specialist reader. It is not suggested that it is easy reading, for it deals with new ideas and theories, with applications in both the biological and the physical sciences. It is clearly written however and does not rely on the use of mathematics to explain the argument put forward. Reviewed in February 1960 *Journal*, p. 117.

BOOTH, A. E. 621.396.029.6

Microwave data tables*

London: Iliffe, 1959. pp. 61. 26 × 19·5cm. 27s. 6d.

These tables of basic relationships include gain and loss in decibels for power, voltage and current ratios, standing-wave ratio, reflection coefficient and frequency.

BRIGGS, G. A., and COOKE, R. E. 534.85

Stereo handbook*

Idle, Bradford: Wharfedale Wireless Works, 1959. pp. 146. 22 × 14·5cm. 10s. 6d.

This non-technical but practical book examines the pros and cons of stereo and some of the problems of choosing, setting up, and using equipment for stereophonic reproduction.

ELECTRICAL DEVELOPMENT ASSOCIATION 621–52

Process integration and instrumentation*

London: Electrical Development Association, 1959. pp. xx, 204. 22·5 × 14·5cm. 8s. 6d.

A simple explanation of the principles of automatic control and automation, including modern techniques, continuous production processes and how these can be controlled by the use of sensing devices and instrumentation linked to control circuits. Examples of applications for a variety of industries and purposes are described. There are many diagrams and illustrations of apparatus and equipment.

GRABBE, E. M., and others (*Editors*) 621–52

Handbook of automation, computation and control. Vol. 2—Computers and data processing

New York: John Wiley. London: Chapman and Hall, 1959. pp. xxiii, 1070. 23 × 15·5cm. £7

This is the second of three volumes. Vol. 1 dealt with Boolean algebra, probability and statistics, numerical analysis, information theory and feedback control. This volume is on computers and data-processing, and Vol. 3 will be on systems and components. Reviewed in February 1960 *Journal*, p. 119.

KNEBEL, K. 621.315.2

Fernsprechkabel für den Weit- und Bezirksverkehr (Ausgenommen Seekabel) (Long-distance cables—excepting submarine cables). **2nd edition**

Goslar: Herzog, 1959. pp. 602. 22 × 15·5cm. £4 10s.

This is a detailed work on the design and manufacture of telephone cables. It deals with the various types, accessories and acceptance tests, including crosstalk and balancing, and the transmission properties of cables generally.

PENESCU, C. I. 621.316.7

Automatica si telemecanica sistemelor energetice—Vol. 1 (Automatic and telecontrol of power systems)

Bucharest: Editura Academiei Republicii Populare Romine, 1959. pp. 785. 24 × 16·5cm. £3 3s. approx.

OTHER PUBLICATIONS

INTERNATIONAL ASTRONOMICAL UNION

Paris symposium on radio astronomy. I.A.U. symposium no. 9 and U.R.S.I symposium no. 1, held from 30th July to 6th August 1958. Edited by R. N. Bracewell

Stanford: Stanford University Press, 1959. pp. xii, 612. 24 × 15·5cm. £6

INTERNATIONAL ELECTROTECHNICAL COMMISSION 413 = 00

International electrotechnical vocabulary group 07, electronics. 2nd edition

Moscow: Gosudarstvenoa Izdatelstvo Physico—Matematicheskoe Literaturi, 1959. pp. 335. 20·5 × 13·5cm. 12s.

413 = 00

International electrotechnical vocabulary group 10, machines and transformers. 2nd edition

Moscow: Gosudarstvenoa Izdatelstvo Physico—Matematicheskoe Literaturi, 1958. pp. 212. 20·5 × 13·5cm. 9s.

The U.S.S.R. National Committee of the International Electrotechnical Commission has prepared these publications of the vocabulary, giving the Russian and English definitions and the terms in the following six languages: French, German, Spanish, Italian, Polish and Swedish.

UNITED NATIONS

Proceedings of the second United Nations international conference on the peaceful uses of atomic energy, held in Geneva 1st–13th September 1958. Vol. 9—Nuclear power plants, Part 2

Geneva: United Nations, 1958. pp. viii, 538. 28·5 × 22cm. £6 5s.

Proceedings of the second United Nations international conference on the peaceful uses of atomic energy, held in Geneva 1st–13th September 1958. Vol. 13—Reactor physics and economics

Geneva: United Nations, 1958. pp. viii, 635. 28·5 × 22cm. £6 12s.

Proceedings of the second United Nations international conference on the peaceful uses of atomic energy, held in Geneva 1st–13th September 1958. Vol. 16—Nuclear data and reactor theory

Geneva: United Nations, 1958. pp. x, 744. 28·5 × 22cm. £6 12s.

District Meetings

ARRANGEMENTS for a District Meeting in April 1960 other than in the area of a local Centre

April 1960

OXFORD (joint meeting with the Institution of Production Engineers at the Council Chamber, Town Hall, at 7 p.m.)

19 *Tuesday* R. O. M. POWELL 'Power-factor correction of industrial electricity supplies'

Forthcoming events at Savoy Place

ALL meetings are held at Savoy Place beginning at 5.30 p.m. (tea at 5 p.m.) except where otherwise stated. The nature of the meeting is indicated by the following key:

ED EDUCATION DISCUSSION CIRCLE
E ELECTRONICS AND COMMUNICATIONS SECTION
I INFORMAL
M MEASUREMENT AND CONTROL SECTION
MED MEDICAL ELECTRONICS DISCUSSION GROUP
O ORDINARY
S SUPPLY SECTION
U UTILIZATION SECTION

March 1960

E **23** *Wednesday* G. MILLINGTON, M.A., B.SC. Lecture on 'The challenge of the propagation medium to the radio engineer'†

ED **29** *Tuesday* G. F. FREEMAN, M.SC.(ENG.), will open a discussion on 'The place of illumination in electrical engineering'* (at 6 p.m., tea at 5.30 p.m.)

S **30** *Wednesday* Section dinner-dance (at the Connaught Rooms, London, at 7 for 7.30 p.m.)

O **31** *Thursday* PROF. C. F. POWELL, M.A., PH.D., SC.D., F.R.S. 51st Kelvin Lecture. 'Cosmic radiation'‡

April 1960

E **4** *Monday* R. V. HARVEY, B.SC. 'V.H.F. sound broadcasting: subjective appraisal of distortion due to multi-path propagation in f.m. reception' (paper 3221E) *synopsis:* see p. 180

M **5** *Tuesday* R. W. A. SCARR, B.SC.(ENG.), PH.D., *and* R. A. SETTERINGTON, B.SC.(ENG.) 'Thermistors—their theory, manufacture and application' (paper 3176M) *synopsis:* January 1960

U **7** *Thursday* G. K. CREIGHTON, B.SC., *and* W. M. SOMERVILLE 'Novel methods of speed control applied to a standard 3-phase squirrel-cage induction motor' (see December 1959 *Journal*, p. 721); R. M. EPPS 'Preset screwdown control in steel-rolling mills'‡; P. J. LAWRENSON, B.SC., M.SC. 'Linear electrical machines'‡ (joint meeting with the London Graduate and Student Section)

E **8** *Friday* Symposium on data-handling and display systems for air traffic control (at 2.30 p.m. and 5.30 p.m.) (all wishing to attend are required to register; forms are available on application to the Secretary of The Institution) (see p. 146)

I **11** *Monday* A. E. J. WHITCHER, B.SC.(ENG.), will open a discussion on 'Public lighting'*

MED **12** *Tuesday* LORD FRASER OF LONSDALE, C.H., C.B.E., *and* R. L. BEURLE, PH.D., B.SC.(ENG.), will open a discussion on 'Aids for the blind'* (at 6 p.m., tea at 5.30 p.m.)

S **13** *Wednesday* C. L. C. ALLAN, B.A. 'Water-turbine-driven induction generators' (paper 3140S) *synopsis:* December 1959

ED **22** *Friday* PROF. H. E. M. BARLOW, PH.D., B.SC.(ENG.), will open a discussion on 'Broadening university courses'* (at 6 p.m., tea at 5.30 p.m.)

M **26** *Tuesday* T. C. CARDWELL, B.SC.(ENG.), J. R. W. SMITH, M.SC., *and* G. H. KING, B.SC. 'An experimental transistor-controlled component selection and testing machine' (paper 3219M) *synopsis:* see p. 180

E **27** *Wednesday* R. CHASTE, ING. É.S.É., L. ÈS SC., *and* P. CASSAGNE, ING. É.S.N.T., L. ÈS SC., 'Henri de France colour-television system' (paper 3251E) *synopsis:* see p. 180

O **28** *Thursday* E. EASTWOOD, PH.D., M.SC. Lecture on 'Radar observations of "birds" and "angels" '‡

* No advance information will be available and no Press report will be permitted
† An abstract will be available in advance
‡ No advance information will be available

Contents of the current *Proceedings*

The date in italics is that of the Journal review, special article, or synopsis. Where given the date in capitals is the month in which a paper or monograph was published individually

PART A. POWER ENGINEERING (FEBRUARY 1960)

See the Journal for February 1960, p. 127

PART B. ELECTRONIC AND COMMUNICATION ENGINEERING (MARCH 1960)

A. E. KARBOWIAK, B.SC.(ENG.), PH.D. PAPER 3132E, OCTOBER 1959 **Some comments on the classification of waveguide modes** *December 1959*

P. GLEGHORN, B.SC.(ENG.). PAPER 2962M, JUNE 1959 **An analogue electronic multiplier using transistors as square-wave modulators** *January 1960*

PROF. A. L. CULLEN, PH.D. PAPER 2991E, AUGUST 1959 **Theory of the travelling-wave parametric amplifier** *December 1959*

J. R. G. TWISLETON, B.SC. PAPER 3031E, OCTOBER 1959 **Some properties of travelling-wave resonance** *December 1959*

A. JURKUS, B.SC., *and* P. N. ROBSON, B.A. PAPER 3017E, OCTOBER 1959 **Saturation effects in a travelling-wave parametric amplifier** *December 1959*

F. KIFT. PAPER 3156E **The propagation of high-frequency radio waves to long distances** *March 1960*

J. K. S. JOWETT, B.SC.(ENG.). PAPER 3169E **V.H.F. field strength measurements over paths in the Irish Sea involving mountain obstacles** *March 1960*

G. D. MONTEATH, B.SC., D. J. WHYTHE, B.SC.(ENG.), *and* K. W. T. HUGHES, B.SC. PAPER 3155E **A method of amplitude and phase measurement in the v.h.f.–u.h.f. band** *March 1960*

R. G. MEDHURST, B.SC. PAPER 3182E **Fundamental and harmonic distortion of waves frequency-modulated with a single tone** *March 1960*

M. F. HOLMES, B.SC., *and* F. H. REYNOLDS, B.SC.(ENG.). PAPER 3163E **Post Office valves for deep-water submarine telephone repeaters** *March 1960*

H. S. WALKER, M.B.E., W. H. ALDOUS, B.SC., R. G. ROACH, B.SC., J. B. WEBB, D.F.H., *and* F. D. GOODCHILD, B.SC.(ENG.). PAPER 3200E **High-power transmitting valves with thoriated filaments for use in broadcasting** *March 1960*

J. VINE, M.SC., *and* R. T. TAYLOR. PAPER 3165M **An improvement to the electron-trajectory tracer** *February 1960*

G. H. RAYNER, B.SC., *and* L. H. FORD, M.SC. PAPER 3159M **Improvements in the precision measurement of capacitance** *February 1960*

PROF. J. G. SANTESMASES, M. ALIQUE, DR.SC., *and* J. L. LLORET, BS.SC. PAPER 3167M **Ferroresonant systems of circuit logic** *March 1960*

F. A. BENSON, D.ENG., PH.D., *and* P. M. CHALMERS, B.ENG. PAPER 3175E **Impedance/frequency characteristics of glow-discharge reference tubes** *March 1960*

H. SUTCLIFFE, M.A. PAPER 3190M **The principle of reversed lag applied to on-off temperature control** *March 1960*

J. WATSON, B.SC., S.M., PH.D. PAPER 3207M **The a.c. operation of ion chambers at high fluxes** *March 1960*

Communicated discussion on **A novel, high-accuracy circuit for the measurement of impedance in the a.f., r.f., and v.h.f. ranges**

PART C. MONOGRAPHS (MARCH 1960)

Communicated discussion on **Eddy-current losses in thin ferromagnetic sheets**

A. S. ALDRED, M.SC., *and* G. SHACKSHAFT, B.ENG., PH.D. 340S, AUGUST 1959 **A frequency-response method for the predetermination of synchronous-machine stability** *August 1959*

J. ROBERTS, B.SC.(ENG.). 341M, JULY 1959 **Analogue treatment of eddy-current problems involving two-dimensional fields** *July 1959*

C. J. CARPENTER, M.SC.(ENG.). 342, AUGUST 1959 **Surface-integral methods of calculating forces on magnetized iron parts** *August 1959*

A. F. HARVEY, D.PHIL., B.SC.(ENG.). 343E, SEPTEMBER 1959 **Microwave tubes—an introductory review with bibliography** *September 1959*

J. K. LUBBOCK, M.A., B.SC.(ENG.). 344E, NOVEMBER 1959 **The optimization of a class of non-linear filters** *November 1959*

H. D. EINHORN, DR.-ING., PH.D. 345U, OCTOBER 1959 **Discrimination between h.r.c. fuses and miniature circuit-breakers** *October 1959*

Contents of the current *Proceedings* (continued)

T. GLUCHAROFF, M.E., *and* C. P. GILBERT, M.SC. 346M, OCTOBER 1959 **The use of silicon diodes in d.c. modulators and their applications to drift correctors for computing amplifiers** *October 1959*

G. H. METSON, M.C., D.SC., PH.D., M.SC., B.SC.(ENG.), *and* EDITH MACARTNEY, M.SC., B.SC. 347E, OCTOBER 1959 **The conductivity of oxide cathodes. 7—Solid semiconduction** *October 1959*

G. S. BROSAN, PH.D., B.SC.(ENG.), *and* D. O. BISHOP, PH.D., B.SC.(ENG.). 348S, NOVEMBER 1959 **An optimum ratio of copper losses and iron losses for a transformer with variable load** *November 1959*

L. SOLYMAR. 349E, NOVEMBER 1959 **A note on the optimum design of non-uniform transmission lines** *November 1959*

O. P. D. CUTTERIDGE, M.SC.(ENG.), PH.D. 350M, DECEMBER 1959 **Some tests for the number of positive zeros and for the numbers of real and complex zeros of a real polynomial** *December 1959*

Communicated discussion on **The stability criteria for linear systems**

D. G. LAMPARD, M.SC., PH.D., *and* R. D. CUTKOSKY, B.SC. 351M, JANUARY 1960 **Some results on the cross-capacitances per unit length of cylindrical three-terminal capacitors with thin dielectric films on their electrodes** *January 1960*

R. G. MEDHURST, B.SC. 352E, JANUARY 1960 **Explicit form of f.m. distortion products with white-noise modulation** *January 1960*

R. J. KAVANAGH, B.SC., M.A.SC., PH.D. 353M, JANUARY 1960 **An approximation to the harmonic response of saturating devices** *January 1960*

Discussion on **Effects of argon content on the characteristics of neon-argon glow-discharge reference tubes** before the Electronics and Communications Section

Communicated discussion on **The square-loop ferrite core as a circuit-element**

Elections and transfers

The following elections and transfers approved by the Council are effective from the 4th February 1960

ELECTIONS: 1st LIST

Graduates

ADAMS, David Compton
BENT, Arthur
BROAD, Roy Marius
BROUGH, Joseph James
BUCK, Colin Patrick
BURTON, Kenneth Robert, DIP.TECH.(ENG.)
CAMPBELL, Neil McKinnon, A.R.C.S.T.
CAPPS, Kenneth Charles
CARRUTHERS, John Anthony, B.A.
CARSWELL, John
CARTER, Richard Malcolm, B.SC.(ENG.)
CLARKE, William Thomas
COLEMAN, Kenneth John, B.SC.(ENG.)
CRABTREE, Raymond
CRISP, Peter Vernon, B.SC.(ENG.)
CROUCH, Joseph Henry
DAVIES, Trefor Lloyd
DUDDLE, Robert
DUKE, Peter William, B.A.
DUN, Saw Chaine
DYMOTT, Peter Harry, B.SC.
EAMES, Roy
ETHERINGTON, Michael
EVANS, Robert Hugh
EYRE, Dennis Arnold Roy
FEKETE, Andrew Gabor, B.SC.
FILES, William Henry
GOSWAMI, Arun, B.SC.
GRANT, James Stevenson, A.R.C.S.T.
HABENS, Bernard, B.SC.
HASTWELL, John Brian, DIP.TECH.(ENG.)
HAYWOOD, Gerald Walter
HERBERT, Anthony Frederick
HIGHFIELD, Barrie Lawson, DIP.TECH.(ENG.)
HIGSON, Geoffrey Brian, B.SC.
HOWITT, Norman Cruickshank
JACKSON, David William
KIRK, John Barry
KOLDIJK, Jelle Gerben
MACDONALD, Alastair Kinross, M.A.
MCKAY, Louis, B.SC.
MCKEAGUE, Roddie, B.SC., PH.D.
MCLACHLAN, William Bruce, B.ENG.
MANGAN, John
MELLOR, Paul, B.SC.
MILES, John David
MILNER, Morris, B.SC.(ENG.)
MOORE, Albert, B.A.
MURPHY, John Michael, B.E.
NASH, Earle Derek
OPONG, Nathan
PARNELL, Garland Owen, B.SC.(ENG.)
PRIVETT, James Henry, B.SC.
PRYKE, Sidney Robert
RAVEN, Peter Francis, DIP.TECH.(ENG.)
RAY, Sasanka Sekhar, B.E.
ROBERTS, William Geoffrey, B.E.
RYDER, John Alan, B.SC.(ENG.)
SADLIER, John Anthony, B.E.
SELDON, John Lindon, B.A.
SIMPSON, Rodney John
SMITH, Derek Travers
STELLING, Anthony, DIP.TECH.(ENG.)
STEVENS, Frederick Robert
TAYLOR, Charles Frederick
TAYLOR, Geoffrey Newton, B.A.
TOMLINSON, Arthur, B.SC.
TRAYLEN, Alfred Henry
THOMPSON, Hugh Patrick, B.A.
TURNBULL, George Frederick, B.SC.
UBOSI, Bertram Ogugua Chukwudozie
WALSH, Steven
WATSON, Christopher Alan, B.A.
WHITEHEAD, Norman Walter
WILBOURNE, Albert Henry
WILLIAMS, Gwilym Wyn
WINSTANLEY, Emyr Hopkin, B.SC.

Students

ADAMIDES, Andreas Georghiou
AHMAD, Syed Abad, B.SC.(ENG.)
AHMED, Ahmed Khalil
AINSWORTH, David
ALEXANDER, Alfred John
AMU, Lawrence Abiodun Oike Giwa
ANDERSON, David Keith
BAKER, Kenneth Alwyn
BALDWIN, David Michael
BALTHAZAAR, Anthony Kenneth Dodwell
BANERJEA, Kalyan Kumar, B.SC.
BANKS, Christopher Wilfred
BARKER, Peter
BATTY, Gordon
BAXTER, Victor Francis
BEALES, Peter John
BEARD, John, B.SC.
BEAUMONT, Antony John
BERRY, David Arthur, B.A.
BERRY, Gordon Frederick
BOLTON, Brian Edward, B.SC.
BOND, Allan
BONNICK, Arthur Sidney
BOYES, Grahame Arthur
BRADING, Edward
BREARLEY, John Samuel
BRIDGE, Raymond Edward, B.SC.
BROWNE, George
BURGE, Bryan
BURKE, Richard Francis
BUTTERS, Dennis Sydney
CAINE, Michael Francis
CARPENTER, David Harry
CARRINGTON, Peter Fredric
CARTER, Bernard Jack William
CASH, James Ouvry
CHAPMAN, Peter David, B.A.
CHAPPELL, Graham Andrew
CHEETHAM, Robert Alfred
CHEONG, Wing Kok
CHOW, Peter El Kwan
CHURCH, David Charles
CLARKE, John Henry
COHEN, Victor
COLLEDGE, Michael John
COOKE, Montague Peter
COSGROVE, Terence Anthony, B.SC.
COWDY, Clive Robin
CROWE, Leslie
DANFORD, Alfred Frederick
DAVENPORT, Peter Lawrence
DAVID, Vivian
DAVIS, Arthur Geoffrey
DAVIS, Michael William
DEL MAR, John Morland
DOD, Derek John
DOLDING, Eric
EDWARDS, Roger David
ELLAMS, Robin
ELSON, Donald George, B.SC.
ELSTEIN, Leslie
ERSKINE, James David
EVANS, David Beris
FARRANT, Edgar Brian
FARRELL, Anthony Henry
FEAR, David, B.SC.
FEWTRELL, Brian George
FOGGO, Stewart Martin
FOY, Kenneth Frank
FREESTONE, Barry Charles
FRICKER, Samuel John
GAMBLE, Keith
GARNER, Robert Michael
GLOVER, John
GOVINNAGE, Kamalasiri Kularatne
GRANT, David Winsor
HARDING, Christopher Francis
HAY, Thomas Turnbull
HILL, Keith Ronald
HINKLEY, Albert Arthur
HOWE, David Albert
HUGHES, Eric John
HALLIGAN, Michael John
HARMER, Daniel Sidney, B.SC.
HEIGHWAY, Robert
HENDERSON, Robert Rait
HOLT, Ian Roscoe
HOMEWOOD, Kenneth Arthur, B.SC.
JARMAN, David Gwyn
JEFFERSON, Frank Jerome
JORDAN, David Edmund
KABBANI, Ousama
KALSI, Balbir Singh
KÁRPÁTI, Kalman
KARUNARATNE, Hidellarachige Don Justin
KAY, Richard
KING, David Christian
LAWES, Ronald Albert
LEA, John Anthony
LEE, Yoon-Fai
LEES, Lawrence
LINDLEY, Keith Allen
LOGAN, Ruth Sheenagh
LOWRY, Peter Charles
LUCAS, Alistair Newton
LYNES, Derek
MCGREGOR, Malcolm Murdo
MADDOCK, Eric George
MAHMUD, Kamal Raji
MAJUMDAR, Dipak, B.E.E.
MATTHEWS, Peter John David
MAY, James
MILLS, Robert Eric
MOHAN, Lalit, B.E.
MOHARE, Chandrakant Karabasappa, B.E.
MORGAN, Eric John
MORRIS, Ralph
MULLINGS, William John
MUMFORD, David Rodney
NANAYAKKARA, Gamage Sydney
NASSE, Cedric Austin Peter, B.SC.
NEWTON, Barrie Hulme
NORRIS, David Walter
O'BRIEN, Terence
ODUNSI, Olatunde Isola
O'DWYER, Kenneth Robert
ORPEN, Vernon Ivan Norman Colin, B.SC.(ENG.)
PALMER, Martin Olaf
PAMPLIN, Hugh Dean
PANG, Soon Ang
PARIKH, Krupesh Kumar Kanchanlal, B.SC.
PATEL, Bhupendra Ramanbhai
PEPPIETTE, Geoffrey Charles Christopher
PERRIS, Michael David
PICKERING, Joseph
POLAND, Laurence John Mel
POLKINGHORNE, Michael John-
PREST, John
PRICE, Colin
RADZI, Muhammad
REED, Michael Branwoods
REID, Neil McCormack
RICHARDSON, Anthony Charles
RILEY, Peter Joseph
ROBERTS, John
ROBERTSON, David Alexander
ROBSON, Norman Walter
ROWBOTHAM, Antony John Rigby
ROWE, Michael John
RULE, Brian Francis
SANGARAPPILLAI, Kathirgamasekarar
SANGSTER, John James
SATURLEY, Brian John
SELBY, James Irwin
SELWOOD, William Frank
SHAW, Derek
SHERING, George Craig
SHEWARD, Peter Thomas
SLAUGHTER, John Keith
SLOANE, Neil James Alexander
SMART, Derek Bowman
SMITH, Barry Sidney
SMITH, Lawrence
SOKOYA, Matthew Olufowobi
SOMERVILLE, Donald Arthur
SPARROW, Herbert Thomas

SPENCE, Edwin Wimperis
SMITH, Stanley
START, Bernard Frederick
SUD, Yash Dev, B.A.
TABER, John Clifford
TAYLOR, Kenneth Alan
TAYLOR, Peter Robert
THORNTON, Richard Hartley
TILLEY, David
TURNER, Alan Bell
TYACK, Graham Edward
VAN DER SPUY, Danie Sybie
VIRDEE, Kulwant Singh
WADE, Barrie Arthur
WADE, James
WALLIS, David Thomas
WALKER, Joseph Anthony
WANNER-HALDER, Michael Richard James
WARDLE, John Meredith
WATSON, John Francis
WHEATLEY, James Alexander McIntosh
WHELAN, Maurice
WHITTAKER, Eric Norman
WHITTLE, Kenneth Lawrence Albert
WHITWORTH, David Arnold
WILKINSON, Geoffrey Foster
WILLIAMSON, Roger Brian, B.SC.
WILLOX, Alexander
WILSON, Bryan John
WILSON, Geoffrey Crompton
WILSON, James Alan
WITHERDEN, Bryan Richard
WOOD, Derek, B.SC.
WOODALL, Geoffrey, B.SC.
WOODS, John Vivian
WOODS, Stanley Frank
WOODS, Stephen Anthony
YARDLEY, Raymond Lloyd
YOUNG, Kenneth

TRANSFERS: 1st LIST

Student to Graduate

ADAMSON, Allan Nicoll Gordon, B.SC.
AKED, Anthony, B.SC.TECH.
ANDREW, Robert Meriton, B.SC.
BACKHOUSE, John Malcolm, B.SC.(ENG.)
BADHAM, Malcolm Fraser Loder, B.SC.(ENG.)
BARKER, Duncan John William, DIP.TECH.(ENG.)
BEASTALL, Harry Rex, B.SC.(ENG.)
BIRCH, David Philip, B.SC.(ENG.)
BONAR, Frank Roberts, B.SC.
BONWITT, Barbara Jean, B.SC.TECH.
BRYCE, Andrew Bonner, B.SC.
CALAZ, Robert Arthur, B.SC.
CALVERT, Thomas William Gillies, B.SC.(ENG.)
CAPEWELL, Peter, DIP.TECH.(ENG.)
CHRISTIE, Ian, B.SC.
COPE, Michael William, B.SC.(ENG.)
COSTIN, John Henry Wallington, B.SC.(ENG.)
DAVIES, Clive Lewis, DIP.TECH.(ENG.)
DE WILTON, Michael Sydney, B.SC.
DOWLING, Daniel Pettitt, B.SC.(ENG.)
EVANS, Bruce
EVANS, Christopher John
FINNAMORE, John Harold
FURNEAU, Alfred Leonard, DIP.TECH.(ENG.)
GARDINER, Derek John, B.SC.
GRAY, John Oliver, B.SC.
HALL, Karl Gerald
HALL, Norman Dennis, DIP.TECH.(ENG.)
HAMILTON, Robert
HEITON, John Raymond, B.SC.
HUGHES, Peter, B.ENG.
HURD, George Alan, B.SC.
JAMES, Leighton Harris, B.ENG.
JENKINS, David Ieuan Thomas
KEARSEY, Roger Patrick
KERR, George, B.SC.(ENG.)
KINSELLA, Terence
KNOX, Barry Sydney David, B.SC.TECH.
LAWTON, Philip John, B.SC.TECH.
LONG, David Peter
LOVIE, David Anderson
LOVIE, Michael Anderson
McCREA, Samuel Brendan, B.SC.
MANNING, Graham Erwin
MARTIN, Ronald Austin, B.SC.(ENG.)
MAVROMIHALES, Andreas John
MURCOTT, Robert James, B.SC.
NICOLL, William McLean, B.SC.
NORFOLK-WILLIAMS, Henry David, B.SC.(ENG.)
O'DOHERTY, Sean, D.L.C.
OWEN, Stanley David, DIP.TECH.(ENG.)
PACKER, Timothy John
PICKERING, James Gordon
PRATT, Phillip John, B.SC.
PRIME, Ronald Clive, B.SC.(ENG.)
ROZENAUERS, Alfred Charles Eustav, B.E.
RUMBALL, Edward Ian, B.E.
SCOTT, James, A.R.C.S.T.
SHEPPARD, John
SMITH, Guy Edmund, DIP.TECH.(ENG.)
SONES, James Harold, B.SC.
STOTT, Colin, B.SC.
TODD, Peter, A.H.-W.C.
TULLETH, Alan, B.SC.
WADVA, Kuldip Singh, B.SC.
WHITE, Brian Glyn
WHITE, William Anthony Thomas, B.SC.
WILLIAMS, John, B.SC.
WRIGHT, Lionel Glyn, B.ENG.

ELECTIONS: 2nd LIST

Graduates

BANNAN, Harry, B.SC.
BLOIS, Anthony Hugh
DE SOYZA, Annesley
DUNLOP, John Brian, B.SC.
DYKES, Roy Selwyn
ELLUL, Oreste
GILMORE, Graeme Bernard
HALY, Edgar Nicholas
HEALEY, Martin, B.SC.(ENG.)
HITCHINS, Derek Kirk
JENNINGS, John Ernest
KELLY, Peter Anthony
LEY, Anthony John, B.A.
MASON, Michael David Lawrence
MOSELEY, George Thomas
NOBLE, John James
NORTON, Douglas Frank
RILEY, Peter John, B.SC.(ENG.)
SANGER, Ishwer Chender, B.E.
SMITH, George Neville
SMITH, Malcolm James Edward
TAYLOR, Alan Philip
TILLMAN, Alan Keith
WATKINS, Leslie Arthur
WATSON, Clifford John
WEST, Denis Rutherford
WHITTAKER, Charles Anthony, B.SC.(ENG.)
WILLIAMSON, Francis Keith, B.SC.

Students

AHMAD, Mushtaq, B.SC.(ENG.)
AKERS, Peter Wilfred
ASHCROFT, Richard Paul
AXE, Roger Austin Charles
BARBER, Brian David
BATES, Jack Osborne, B.SC.
BOND, John William
BRISTER, David Frederick Edgar
BROWN, Geoffrey Edward
BUTLER, Christopher John
BYRON, John Raymond
CHARLES, Barry John
COLLINS, Peter Malcolm
COOGANS, John Joseph
COOMBS, Geoffrey Brian, B.SC.
COOPER, Derek Anthony

Students (continued)

COSTELLO, John Robin
CRANCHER, Walter John
CRAWFORD, David Henry
CRETNEY, Wilfred Allan
DHRUVAN, Srinivasa, B.E.
DRISCOLL, Edward Thomas
EASTWOOD, Peter Leslie, B.SC.
EPPS, John Anthony
GEALE, Audrey Anne
GEORGE, Graham Emlyn
GHOSH, Kamal Kumar, B.SC.
HARRIS, Henry Lewin
HARRIS, John Frederick
HILLIER, Alan Joseph
HOPKINSON, Philip Hugh
HUNKIN, Terrence David Philip
IVES, Lesley Veronica
JAMES, Roger
LONG, Andrew Marsden
LUTER, Michael Edward
MACLEOD, Alexander Robertson
MORGAN, Thomas Geoffrey
MOSS, James Arthur
NINNIM, Nicholas James Henry
ORMAN, Gerald Anthony Edward
RAVEN, Barton
REID, Daniel McCormack
RHODES, Trevor John
RODD, Eric George
ROSS, Peter Nigel
SCOTT, David Iain
SCOTT, Russell
SMITH, Alan
SMITH, Michael John
SMITH, Thomas Alexander
STICKELLS, Frederick George
STREATER, Barry Brangwyn
SWAMPILLAI, Cecil Reginald
TAIT, Sinclair
TATTERSALL, Eric Beaumont
THORP, Gerald
TINSLEY, John Michael
TODD, Paul Clements, B.SC.
TURNER, David Charles
WEBSTER, Antony Graham
WHITELEY, Barrie Neil
WILLS, Henry George

TRANSFERS: 2nd LIST

Student to Graduate

ACHARYYA, Susil Chandra, B.E.E.
ARMITAGE, John Turner
ATKINSON, Peter
BAKER, George Edward March, B.SC.
BENDING, Brian Thomas, B.SC.(ENG.)
BISHTON, Martin Howard, DIP.TECH.(ENG.)
BOYCE, Kenneth Ronald
BROWN, Kenneth, B.SC.
BYNE, Hugh Trevor Whittingham, B.SC.(ENG.)
CAREY, David John, B.ENG.
CHARD, John Anthony
DRAPER, Stanley William, B.SC.
FAWCETT, Brian Jack
FERRETT, Neil Antony, B.SC.
FIELDER, Lawrence Henry, B.SC.
FOGARTY, George William Alexander, B.SC.
FOSTER, Harold
GREGORY, Peter
GRESHAM, Robert James
HALE, Clifford, B.SC.(ENG.)
HARGREAVES, Peter, B.SC.TECH.
HOCKENHULL, Nicholas Charles Heddington
HOLLIS, Frank Charles
HORROCKS, Daniel Edward
HOUSTON, David Andrew, DIP.TECH.(ENG.)
HUGHES, Edward John Stuart, B.SC.(ENG.)
IVESON, Albert John
JACKSON, Raymond Leslie, B.SC.(ENG.)
JONES, Kenneth Barrie
LAMBERT, Peter Gabriel, B.SC.(ENG.)
LANE, David Howard, B.SC.
LEIGH, Ashley Paul, B.SC.
LEWIS, Vernon John, B.SC.
LISTER, Robert Malcolm
LLOYD, Denis George, B.A.
McWATT, Edward Jerome, B.ENG.
MASTERMAN, John Michael, B.SC.
MILES, Clifford Victor Harry, B.SC.
MILNE, Ian James, B.SC.
MORRIS, George Edwin, B.SC.
MOYS, Robin Gerald, B.SC.(ENG.)
NACASKUL, Paibul, B.SC.
NADZIM, Mohamed, B.SC.(ENG.)
NICOLSON, Alexander Murray, B.SC.
NORRIS, Paul Mitchell
OSWAL, Dongerchand Dalichand, B.E.
PAYNE, David Malcolm
PEEBLES, Ronald Edward
PIERCE, Reginald Roy
PODESTA, Albert Joseph, B.SC.TECH.
ROACH, Maurice Leslie
ROBERTS, John Arthur, B.SC.TECH.
ROBINSON, Alfred Henry, B.SC.(ENG.)
SHARPLEY, William Barry, B.SC.
SMITH, Philip John Mytton
STUBBS, Michael John, B.ENG.
SUNTHARALINGAM, Nagalingam, B.SC.
TAMBLYN, Anthony Clive John, B.SC.
TAN, Aik Hye, B.SC.(ENG.)
TAYLER, Brian Horace Everard
THICKPENNEY, John
THOMAS, David John
THORNCROFT, Roy Charles
TRACEY, Peter Martin
WALDRON, Thomas William
WARNER, Philip Barry
WATT, Alan Vallack
WESTON, Anthony Ashby
WHITELEY, Michael Christopher
WILLDEY, Geoffrey Michael, B.SC.

British Nuclear Energy Conference

DETAILS of a forthcoming meeting of the British Nuclear Energy Conference are given below. Tickets of admission are not required

1960

MARCH 30 *Wednesday* (10 a.m.)

Sponsoring society: The Institute of Metals
Place of meeting: Hoare Memorial Hall, Church House, Westminster, London S.W.1

SPRING MEETING

Discussion on the paper VOLUME INCREASES IN FISSILE MATERIALS ON NEUTRON IRRADIATION AND THE EFFECTS OF THERMAL FLUCTUATIONS G. W. Greenwood

Members wishing to contribute to the discussion are asked to write to the Secretary of The Institute of Metals, 17 Belgrave Square, London S.W.1, as soon as possible

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 19TH FEBRUARY 1960

	No. of contributors	£	*s.*	*d.*
£1000 and over	8	8685	0	0
£100 to <£1000	32	7181	3	0
£5 to <£100	905	9448	19	3
£2 to <£5	2227	6135	8	1
under £2	28201	14750	13	7
		£46201	3	11

PATRON OF THE INSTITUTION

THE following message was delivered to Buckingham Palace on the afternoon of Friday, 19th February 1960:

'*To The Queen's Most Excellent Majesty:*

The President and Council of The Institution of Electrical Engineers present their humble duty to Her Gracious Majesty, their Patron, and offer their sincere congratulations on the birth of a Prince. They pray that Her Majesty and the infant Prince will long enjoy health and happiness and, in so doing, express the wish of all the members of this Institution.'

Her Majesty's Private Secretary replied the next day as follows:

'*President, The Institution of Electrical Engineers:*

Please convey the sincere thanks of The Queen and The Duke of Edinburgh to all those associated with you in your kind message of congratulations on the birth of their son.'

ELECTION OF HONORARY MEMBERS

AS reported on p. 156, the Council of The Institution have elected to Honorary Membership:

Col. B. H. Leeson, C.B.E., T.D., PAST-PRESIDENT, in recognition of his extensive contributions to the application of electrical science and engineering in the manufacture of electrical plant and equipment, to the development of co-operative effort within the electrical industry and to the training of electrical engineers, and of the services he has rendered to The Institution over nearly half a century.

Dr. Richard L. Hearn, B.A.SC., LL.D., for his notable contributions in the development of electricity generation and its supply for the benefit and use of mankind, particularly in Canada, and for the part he has played in international co-operation in this field.

Normally only one Honorary Member is elected each year, but once in every period of three years the Council are empowered to elect an additional Honorary Member who is not, at the time of his election, a member of any class of The Institution. Dr. Hearn's election was made in this category.

38th AWARD OF THE FARADAY MEDAL

THE Council of The Institution have awarded the Faraday Medal to **Sir George Thomson,** D.SC., F.R.S., in recognition of his outstanding contribution to the advancement of electrical science, of the leadership in research which he has given to others in this field, and of his inspiring services to education in science and technology (see p. 156).

APPOINTMENTS AND NOMINATIONS

COMMITTEE ON RADIO INTERFERENCE

ON the nomination of the British Medical Association the Council have appointed Dr. P. Bauwens, M.R.C.P., to serve on the above committee for a further term of three years ending the 31st December 1962.

On the nomination of the Admiralty the Council have appointed Mr. T. Morgan to serve on the above committee in succession to Lt. J. N. Wishart, R.N., ASSOCIATE MEMBER.

JOINT COMMITTEE ON MODEL FORMS OF GENERAL CONDITIONS OF CONTRACT AND COMMITTEE ON MODEL FORMS OF GENERAL CONDITIONS OF CONTRACT (ELECTRICAL)

On the nomination of the Cable Makers Association the Council have appointed Mr. G. V. Tew to serve on the above committees in place of Mr. E. J. Gibbons.

B.S.I. SUB-COMMITTEE ELE/82/3—ELECTRICALLY HEATED CARPET UNDERLAYS

The Council have nominated Mr. C. E. Mills, MEMBER, as their representative on the above new sub-committee.

B.S.I. TECHNICAL COMMITTEE E/149—INPUT AND OUTPUT STANDARDS FOR DATA-PROCESSING EQUIPMENT

The Council have nominated Mr. W. S. Elliott, M.A., MEMBER, as their representative on the above committee in place of Mr. R. H. Tizard, B.A., MEMBER.

NATIONAL PHYSICAL LABORATORY—GENERAL BOARD

The Council have nominated Sir Harold Bishop, C.B.E., B.SC.(ENG.), PAST-PRESIDENT, as their representative on the above board instead of Mr. J. R. Beard, C.B.E., M.SC., PAST-PRESIDENT, who is unable to undertake this duty.

LOUGHBOROUGH COLLEGE OF TECHNOLOGY, GOVERNING BODY

The Council have nominated Mr. G. S. C. Lucas, O.B.E., F.C.G.I., MEMBER, as their representative on the above governing body.

NOTTINGHAM TECHNICAL COLLEGE, ELECTRICAL ENGINEERING ADVISORY COMMITTEE

The Council have nominated Mr. R. H. Price, MEMBER, as their representative on the above committee.

CONFERENCE ON NON-DESTRUCTIVE TESTING

8TH–10TH NOVEMBER 1961

THE Measurement and Control Section of The Institution, in association with the British National Committee on Non-Destructive Testing, is organizing a conference on non-destructive testing in electrical engineering to be held at Savoy Place from the 8th to 10th November 1961. The theme of the conference will be 'How best may the electrical engineer test the quality and endurance of his materials and structures?'

The Organizing Committee of the conference will be pleased to consider papers on the following and allied subjects:

1. Testing of materials—plastics, rubbers, laminates, glasses, ceramics, enamels, anodic coatings, papers, plastic foils, insulating liquids, metallic foils, and magnetic materials
2. Detection of impurities and inclusions in insulation
3. Proof and maintenance tests on insulation, including measurement of discharge-inception stress; measurement of loss angle and conduction; and overvoltage tests
4. Detection of defects in insulators and bushings
5. Electrical and mechanical tests on cables, cable sheaths and cable accessories
6. Detection of concealed internal features, such as cable cores and potted components
7. Testing of interfacial contacts and joints (electrical and mechanical)
8. Detection and damping of vibration
9. Testing of thin insulating coatings on metals
10. Detection and measurement of leaks in electrical equipment (gases, liquids and micro-organisms).

Full details regarding the procedure for the preparation of papers are available on application.

Papers submitted for consideration should not be longer than 8500 words; short papers of about 500–1000 words will also be welcomed. It will greatly assist the Organizing Committee in planning the programme for the conference if prospective authors will send résumés of their proposed papers as soon as possible; these and subsequent manuscripts should be submitted in triplicate to the Secretary of The Institution as soon as possible and in any case not later than the 31st May 1961.

It is hoped that facilities will be available during the conference for authors who so wish to display small items of apparatus connected with the presentation of their papers.

STUDENTS' QUARTERLY JOURNAL

THE history and development of radar are discussed by J. P. Kenny in the March 1960 issue of the *Students' Quarterly Journal*. Additional light-current topics dealt with are electronics and the recurrent-surge oscillograph, the latter by G. E. Woolley. Other aspects of electrical engineering are covered in articles on linear electrical machines by P. J. Lawrenson, automatic control of hydroelectric stations by K. von Krogh, the control of nuclear reactors by R. B. Coates, and pulses and transformers by G. F. Gare.

Flour-milling control is considered in an article by T. W. Davies and the issue is completed by information on 1960 scholarships, reviews of new books, letters from readers, and Section reports.

PROBLEMS OF ENGINEERING EDUCATION

CORRECTION

IN the report of the group of German professors on p. 421 of the December 1959 issue of Part A of the *Proceedings* it was stated in error that the courses at the Battersea College of Advanced Technology are not honours-degree courses. In fact Battersea produces a high proportion of honours graduates, and it is regretted that the error was not noticed before publication.

FUEL EFFICIENCY AND POWER FOR INDUSTRY EXHIBITION

THE Fuel Efficiency and Power for Industry Exhibition will be held in the National Hall, Olympia, London, from the 27th April to 6th May 1960.

A committee convened by The Institute of Fuel have arranged a series of technical meetings to coincide with the exhibition, and the meetings will be held in the Conference Hall at Olympia on the 2nd and 3rd May 1960. The Institution, together with a number of other bodies, is represented on the committee.

The general title of the meetings is 'The selection of fuel-using equipment and power plant', and papers will be presented and discussed according to the following programme:

Monday afternoon, 2nd May

2.15 p.m. Opening of the meetings by Dr. A. C. Monkhouse

2.20–3.45 p.m.: Session 1
'Effective combustion in steam boilers' by D. C. Gunn

4.05–5.30 p.m.: Session 2
'Efficient use of electricity in industry' by W. J. Dickie

Tuesday afternoon, 3rd May

2.15–3.45 p.m.: Session 3
'Heat transfer' by R. F. Hayman

4.15–5.30 p.m.: Session 4
'Heat losses' by J. H. G. Bilney and 'Heat recovery' by F. H. Newman

Advance copies of the papers to be presented will be available without charge at the meetings or on request beforehand (after the 14th April), covered by 9d. for postage and packing, from the Secretary of The Institute of Fuel, 18 Devonshire Street, Portland Place, London W.1, to whom requests for tickets of admission (stating sessions required)

should also be addressed, the envelope being marked 'Olympia' in the left-hand top corner. The meetings are open to the public and admission is free.

ILLUMINATING ENGINEERING SOCIETY

SUMMER MEETING, 1960

THE biennial summer meeting of the Illuminating Engineering Society will be held at Harrogate from the 15th to 18th May 1960.

The number of formal papers has been reduced to three, and one day will be devoted to the study and discussion of technical subjects of wide topical interest. The three papers deal with progress in the field of electric lamps; rationally recommended illumination levels; and plastics yesterday, today and tomorrow.

Topics of the discussion meetings on the 17th May include task analysis, luminance and glare, modelling and colour, industrial area floodlighting, maintenance and lighting calculations.

Attendance at the meeting is not confined to members of the Society, and further particulars may be obtained from the Secretary of the Society, 32 Victoria Street, London S.W.1.

WHITWORTH FOUNDATION AWARDS 1961

THE new arrangements for the annual award of Whitworth Fellowships and Exhibitions were given on p. 399 of the June 1959 *Journal*. The Minister of Education offers for competition in 1961 Whitworth Fellowships, not exceeding three in number, normally tenable for at least one year, with a value of £1000 a year which may be supplemented by various allowances according to the circumstances of the candidate and the nature of the course of training, study or research undertaken; and Exhibitions of £100 each, not exceeding three in number, to unsuccessful competitors whose work deserves recognition, to be spent on furthering the competitor's education in a manner approved by the Minister.

British subjects over 25 years of age are eligible to compete for an award provided that they have not previously held a Fellowship or a Senior Whitworth Scholarship. They must hold either a university degree in engineering, a Diploma in Technology (Engineering), a Higher National Diploma or Higher National Certificate in engineering with at least two distinctions, or a qualification approved by the Minister as of equivalent standard to one of the above. They must subsequently have been engaged as practising engineers for not less than three years.

Candidates will be required to furnish on a prescribed form particulars of their career and experience in engineering. From these applications, selected candidates will be called for an interview at which the Ministry will decide on who should submit theses. Whitworth awards will be made on the results of the theses and a further viva voce examination of the candidates.

Applications should be made on form 51.F.E. (1961) as soon as possible, and in any case not later than the 31st July 1960. Inquiries and requests for application forms should be made to the Secretary, Ministry of Education, (F.E.1 (C)), Curzon Street, London W.1.

PRODUCTIVITY—MEN AND METHODS

THE British Productivity Council are organizing a conference entitled 'Productivity—men and methods' which is to be held at Olympia, London, from the 25th to 29th April 1960 during the period of the Production Exhibition.

The eight half-day sessions will deal with computers and production control, fitting the job to the worker, work study and industrial engineering, variety reduction, quality control, communications in industry, training of supervisors, and organizing for cost reduction.

Tickets (price 25s. each per session) and further information may be obtained from the British Productivity Council, 21 Tothill Street, London S.W.1.

WORLD POWER CONFERENCE

MADRID SECTIONAL MEETING

COPIES of the general programme issued by the Spanish National Committee in connection with the Sectional Meeting of the World Power Conference to be held in Madrid from the 5th to 9th June 1960 are now available and may be obtained from the Secretary, British National Committee of the World Power Conference, 201–2 Grand Buildings, Trafalgar Square, London W.C.2. Each copy sent to an address in the United Kingdom is accompanied by a fully-explanatory covering letter. All membership applications must be submitted through the British National Committee; the necessary forms, including applications to participate in one of the six alternative post-conference study tours, are contained in the general programme.

The general theme of the meeting is 'Methods for solving power-shortage problems'. The five sections of the meeting are entitled: Methods of investigation of energy sources and requirements; Efficiency of production and utilization of energy; Technical developments in transportation; Establishment of nuclear reactors on an industrial scale; and Functional interrelation between conventional and nuclear production of energy.

OVERSEA ATTENDANCE REGISTER

DURING the period 17th December 1959 to 16th February 1960 these members called at the Institution building and signed the Attendance Register of Oversea Members:

ALGATE, L. J. (Adelaide)
ANGUS, G. H. (Lagos, Nigeria)
APSIMON, W. I. (Freetown, Sierra Leone)
AUERBACH, J. (Tel Aviv, Israel)
BANKS, E. J. K. (Kuala Lumpur, Malaya)
BOOTH, G. H. (Ottawa, Ontario)
BOZZOLI, G. R. (Johannesburg)
BRAZEL, L. W. (Calcutta)
BRIARS, E. (Nicosia, Cyprus)
COWEN, A. B. (Salisbury, S. Rhodesia)
ELNÉKAVÉ, N. (Paris)
FERNANDO, P. B. N. (Colombo, Ceylon)
FURBER, H. D. (Tripoli, Lebanon)
GIBSON, A. E. C. (Karachi)
HARMER, L. B. (Hamilton, Bermuda)
HOLIDAY, A. (Kaduna, Nigeria)
LYE, F. Y. (Kuala Lumpur, Malaya)
MURRAY, C. C. (Accra, Ghana)
NISBET, R. B. R. (San Fernando, Trinidad)
PARAMESVARAN, T. V. (Colombo, Ceylon)
POTWOROWSKI, T. (Caracas, Venezuela)
REDDYHOUGH, H. L. (Aden)
ROOTS, W. K. (Los Gatos, California)
STEPHEN, K. (Christchurch, N.Z.)
TALBOT-JONES, R. V. (Hong Kong)
TURNER, C. A. (Wellington, N.Z.)
USHER, R. A. R. (Singapore)

ORDINARY MEETINGS

Second Hunter Memorial Lecture

THE name of P. V. Hunter is the latest to be added to the roll of distinguished men associated with an annual lecture. The Second Hunter Memorial Lecture was given on the 7th January 1960 at Savoy Place by Mr. H. G. Bell. An article based on the Lecture will be included in the *Journal* in due course.

The curtain rose (literally, of course) on a scene sketched on the blackboard by the Lecturer, depicting a group of interconnected generating stations, complete with smoking chimneys. This mildly humorous touch was one of many that enlivened the evening's proceedings and that made it possible to say truthfully that they were enjoyable. The President then introduced Mr. Bell, if that is applicable to one who was so obviously well known to his audience.

The Lecturer began with a reminder that Mr. C. O. Boyse had given the first Lecture and went on to mention the series of three 'named' Lectures. Of these, he placed the present one about midway between the Faraday and the Kelvin Lectures, since it was the intention that the wide band of subjects that came within the late Mr. Hunter's grasp should be dealt with in successive Lectures. Prominent among these subjects was power-system protection, in which he was a pioneer worker with others now famous, like himself, for having developed and patented protective schemes so soundly and fundamentally conceived that the basic principles are still in use even in modern schemes.

Protection of electrical systems

Mr. Bell might have explained that 'bias' was not among the early principles; but seemingly his own natural bias towards protection had led him to choose as the subject of his Lecture 'The protection of electrical systems'.

Since to encompass this subject in a Lecture lasting less than 90 minutes is an impossible task (indeed, little less would be needed to do justice to any one of the dozen subdivisions into which he had chosen to split it), only two ways of approach are really possible. One is an engineering approach by which the principles of design and application of the different systems can be explained; and the other a popular approach by which an over-all picture in detail of the background of protective-gear practice can be presented.

The first would lead virtually to a quintessence that only the specialist would comprehend; and, since the Lecture was avowedly aimed at the non-specialist, the second was the obvious choice. It had the added merit of permitting the inclusion of historical matter, so necessary if P. V. Hunter's influence on the development of protection is to be properly appreciated.

There were also predictions of future trends in the design of protective devices, but in that of relays rather than schemes about which prophecy, fettered by commercial discretion, is likely to be too speculative. There were even quotations from Shakespeare ('O! for a Muse of fire . . .': *King Henry V*, Chorus, Act 1).

Demonstration of fault clearing

But for the many non-specialists in the well filled Lecture Theatre the high-light must have been the attractive panel and the demonstration with it of life-size protection operating to clear faults on a model in miniature of the power circuits of an electric railway. The panel was a large photograph of a part of the actual Manchester–Crewe railway track and 25kV overhead equipment, surmounted by a diagrammatic representation of the overhead circuits of the two tracks with coloured lamps representing the circuit-breakers and genuine distance-type relays adjacent to them.

An assistant, with the aid of pushbuttons, applied faults at various points within and beyond the two circuits. As predicted by Mr. Bell, keeping his fingers crossed, all the faults (each accompanied by a realistic crack and flash on the mimic diagram and a glowing of the offending polluted insulator on the photograph) were cleared with perfect discrimination, all in accordance with the dictates of the prescient distance relays.

These operations were accompanied by a running commentary permitted by the necessity to slow them down so that the sequence of trippings, too rapid in real life to be followed, could be seen. Polluted insulators were the penalty of running steam trains but, in any event, it would not have been practicable, photographically speaking, to put faults out on the conductor.

The 'named' Lecture is always an occasion for double honours—it honours him that gives it and the one named. This, though it may not be intentional, is inevitable; and when the Lecture is the obvious success that this one was, it places on those who accept the pleasant duty of proposing a vote of thanks the delicate task of holding a nice balance between the legitimate deserts of the Lecturer and those of the man commemorated.

Mr. C. T. Melling performed it perfectly, with quotations from Shakespeare aptly capping those of the Lecturer; so aptly, in fact, that even the less suspicious-minded of the audience might have been excused for thinking that there had been collusion. (In fact, there had been none.) It was characteristic of him that he also thanked the fault-throwing assistant, Mr. T. Davies. M. K.

Radiocommunications by means of satellites

DR. A. W. Lines opened his presentation of a most interesting lecture at Savoy Place on the 28th January 1960 by considering three broad classifications of satellite communication system: (1) orbiting storage/delayed-repeater; (2) orbiting real-time; and (3) stationary real-time.

The first has already been demonstrated and he confined himself to categories (2) and (3), either of which can be based on active repeating or passive reflecting satellites. Since the

London report (continued)

passive systems pose the most difficult and interesting problems he concentrated on these.

Several papers have appeared on the second category and the work of Pierce and Kompfner was quoted. This shows that for stations operating between the Hebrides and Newfoundland a passive system based on spherical reflecting satellites is possible with a satellite diameter of about 100ft. Such a satellite placed in a circular polar orbit at a height of a few thousand miles is simultaneously 'visible' from both stations for part of its orbit. To provide reasonable time coverage a number of such satellites are needed. In random orbits at 3000 miles altitude, 24 satellites would provide coverage for 99% of the time with sighting at more than 7·25° above the horizon.

A 5Mc/s band-width system with a 40dB signal/noise ratio could be based on an 85kW transmitter at 2000Mc/s using 150ft-diameter aerials. With an aerial beam width of only 0·2° precise following of the satellite would be needed and the over-all ground installations would be complex. A substantial reduction in the number of satellites would result if they were spaced accurately in orbit, and a practical approach would be to launch a small number initially with correct spacing and then fill up the gaps resulting from a slow deterioration of spacing.

Stationary orbit

Turning to the third category the lecturer pointed out that an easterly travelling satellite in a circular Equatorial orbit with a period of 24h (radius from the Earth's centre about 22750 nautical miles) would appear stationary from the Earth. At such a height, a single satellite could see some 42% of the Earth's surface and with three, equally spaced, this figure rises to over 98%. On the Earth's surface, the visible coverage takes the form of cones intersecting a sphere. With multiple satellites the latitude of intersection of the cones is of interest and for three satellites would be at 72½° rising to 81½° for an infinite number of satellites (i.e. maximum latitude visible from this orbit radius). If sights at 5° above the horizon are considered, the last two figures are reduced to 62° and 76½°.

To put a payload in this stationary orbit needs about the same propulsion performance as to carry the payload to the moon. Each pound of payload requires about 1000lb of take-off thrust; for the 800lb Russian payload to the moon something like 750000lb of thrust for take-off is needed. For a passive system, simple scaling from the 3000-mile-altitude orbit suggests reflecting spheres of about ½-mile diameter, and these are likely to weigh some 50000lb.

There is little hope of putting such payloads into this orbit but the great importance of satellite simplicity, and hence reliability, makes a passive system very attractive. A directive reflector can be visualized as a small cap of the ½-mile-diameter sphere, perhaps 200–300ft across, but this would have to be stabilized. To retain simplicity a simple stabilization system is needed, and with appropriate satellite mass distribution this might be based on the very small torque arising from the gravity-field gradient. Care would be needed to reduce disturbing torques, such as arise from the sun's radiation, and damping of oscillations would have to be provided.

Guidance and control

Dr. Lines went on to suggest that the key to the stationary-satellite approach was in the guidance and control problems. Very high accuracy in achieving the correct orbit is needed to ensure a long useful life. This was illustrated by the following table giving the order of magnitude of velocity accuracy needed for various tasks:

To hit moon	about 100ft/s
To circle behind moon	about 10ft/s
Ballistic missile	about 1ft/s
Stationary communication satellite	better than 0·1ft/s

Such an accuracy by direct means was probably beyond our ability, but, since the satellite would appear almost stationary, long-period observations from a fixed site would enable the orbit correction needed to be measured with more than adequate precision, and a controlled correction impulse could then be applied provided that the stabilization problem had been solved.

The lecturer stressed the difficulty of quoting firm figures for the cost of developing satellite communication systems. The fact that these figures were high, perhaps £500–1000 million for the stationary system, did not necessarily mean that this approach to a high-capacity long-range communication system was economically unsound since such systems apparently had also a large earning capacity. J. S. M.

DISTRICT MEETINGS AT OXFORD

Electrical installation practice

At a meeting at the Southern Electricity Board's District Office in Oxford on the 20th January 1960 Mr. J. L. Taylor introduced Mr. E. J. Sutton, chief technical officer of the National Inspection Council for Electrical Installation Contracting, who spoke on 'Electrical installation practice'. Some members of the Oxfordshire Association of Architects attended by invitation.

Mr. Sutton explained why the N.I.C.E.I.C. was formed, clarifying its aim and application to electrical contractors, nationalized boards and electricity consumers. The structure of the organization was described and a brief history given of its progress since its inauguration on the 1st January 1957.

To emphasize the importance of having a body such as the N.I.C.E.I.C. the lecturer used slides showing examples of bad and dangerous installations, some of which, if it were not for the seriousness of the matter, would be quite comical. Also illustrated were some modern developments in installation technique.

After the refreshment break Mr. Sutton answered a variety of questions. The meeting closed with a vote of thanks by Mr. C. L. Cottell, Hon. Secretary, Oxfordshire Society of Architects. J. L. T.

Deltic locomotive

Forty-five members and visitors were at the Southern Electricity Board Service Centre, Oxford, on the 10th February

1960 to hear Mr. G. V. Davey present a paper on 'The Deltic locomotive' on behalf of the author, Mr. C. M. Cock (the paper was reviewed in the March 1959 *Journal*, p. 155).

He outlined the difficulties encountered in designing a locomotive in present-day conditions, especially with the large electrification programme which the British Transport Commission has formulated.

He described with the aid of slides the construction of the locomotive and of the power unit. The reasons for the choice of power unit and its advantages were explained.

He briefly considered the economics of railway traction, and he illustrated his remarks on engine maintenance by a short colour film showing a power-unit change on a Deltic locomotive.

A short break for coffee was followed by a lively question period in which Mr. Davey ably dealt with such diverse topics as the use of sand to prevent wheel slip, preheating of coaches, and shunt field-weakening for speed regulation.

Mr. W. H. Lee moved a vote of thanks which was enthusiastically supported. J. W.

BULLETIN OF THE SECTIONS

ELECTRONICS AND COMMUNICATIONS

Coming shortly

On the 4th April 1960 Mr. R. V. Harvey will present his paper 'V.H.F. sound broadcasting: subjective appraisal of distortion due to multipath propagation in f.m. reception' and will include aural and visual demonstrations of distortion in simulated propagation conditions.

Mr. Harvey was born in 1923 and was educated at Caterham School, Surrey. He studied electrical engineering at Faraday House, where he obtained the Diploma. From 1943 to 1947 he was with the Receiver Group at the Telecommunications Research Establishment (now R.R.E.), Malvern. He studied physics at King's College, London, graduating in 1950. He then joined the B.B.C. Research Department, where he has been engaged in problems of radio-frequency reception and measurement.

M. R. Chaste *M. P. Cassagne*

Colour television

On the 27th April 1960 MM. R. Chaste and P. Cassagne will present their paper 'Henri de France colour-television system'.

M. Chaste, who was born in Paris in 1928, graduated in 1948 and received the L. ès Sc. degree in 1952. He has been with the Compagnie Générale de T.S.F. since 1950.

M. Cassagne, who was born in 1924 at Montauban, is a graduate of Toulouse University and was awarded the M.Sc. degree in 1949. He has studied colour-television problems since 1951. He is a member of the research staff of the Compagnie Française de Télévision.

It is hoped that it will be possible to arrange a live demonstration of the system.

Laying submarine cables

On the 16th December 1959, with Mr. M. J. L. Pulling in the Chair, there was at Savoy Place a very enjoyable and rather unusual lecture by Capt. W. H. Leech, submarine superintendent, Post Office, on 'The laying of submarine cables'. Capt. Leech has previously entertained us during discussions with his salty comments, and his lecture was characteristic. He was primarily concerned with the long repeatered transoceanic telephone cables which present many new and difficult problems. He explained the new techniques which have had to be devised for the laying and repairing of coaxial cables of both conventional (i.e. armoured) and unarmoured types.

H.M.T.S. *Monarch* was the last ship built (in 1946) primarily for cable laying, and extensive alterations have been carried out in recent years, both for laying American flexible repeaters as in the first transatlantic telephone cable and more recently for laying rigid repeaters of British and American design. A new ship, which as 'No. 801' has not yet developed a proper personality, is now being built for the Post Office. The lecturer described the ship and the new techniques which are being built into it for loading, stowing, laying and testing the complex of cables, repeaters and equalizers.

The discussion was opened by Sir Gordon Radley who paid tribute to the lecturer as one of the few experts in this field. After mentioning novel design features incorporated in earlier cable-laying ships he ranged over the many problems of laying modern repeatered systems and stressed the urgent need for 'No. 801'. Other speakers contributed to a lively discussion including Mr. J. A. Smale who thought there was still something to be said for radio. Capt. Leech replied briefly but adequately. R. J. H.

Modulators, sidebands and distortion

Three papers were presented at a meeting at Savoy Place on the 11th January 1960. They were: 'A quadrature network for generating vestigial-sideband signals' by G. G. Gouriet and G. F. Newell; 'Rectifier modulators with frequency-selective terminations' by D. P. Howson and Prof. D. G. Tucker; and 'The input impedance of rectifier modulators' by Prof. D. G. Tucker. They are reviewed on pp. 166 and 167.

Mr. Gouriet gave his paper first and clearly summarized the theory and practice behind his method of producing a vestigial-sideband signal free from phase distortion. He mentioned his indebtedness to some work by D. Gabor in 1946 discussing the significance of quadrature signals. In conclusion, results obtained on experimental equipment were shown to indicate close agreement between theory and measurement.

Prof. Tucker presented the next two papers, explaining that the objective in his first was to establish a basis for the calculation of modulation products in various types of rectifier modulator and to determine the conditions in which no even-order modulation-product currents were produced.

In the second paper the results of the first had been applied to the calculation of input impedance, which was shown to have the peculiar property, in most conditions, of being dependent on the impedance of the signal source.

Clarity and obscurity

In the discussion which followed, the comments and questions were directed mainly to Mr. Gouriet's paper.

Mr. G. D. Monteath doubted whether changing over from the existing system of television transmission to that proposed by Mr. Gouriet would yield the improvements claimed; the likely increase in receiver costs (owing to the need for extra bandwidth and more gain) had been estimated at $5 in the United States.

Mr. B. B. Jacobsen thought that much of the mathematics in the Gouriet paper tended to obscure rather than clarify the physical concept of a quadrature signal; other speakers disagreed with this comment. More than one speaker pleaded for clearer definitions of single sideband and vestigial sideband, with which view Mr. Gouriet fervently agreed.

Mr. D. Maurice described some numerical exercises which he had carried out in order to assess the probable improvements resulting from the Gouriet proposals; the system appeared to have disadvantages when a colour carrier signal was present.

The paper on rectifier modulators provoked little discussion except that one speaker wanted to know why it was so important to remove even-order modulation-product currents.

Mr. Gouriet's replies to the questions and criticisms were, as always, models of clarity and good humour.

In closing the meeting, the chairman, Mr. T. B. D. Terroni, called attention to the common factor in the three papers which had been presented, namely the problem of producing wanted sidebands in a finite bandwidth. L. I. F.

Talking about science

THAT problems of presenting information are of perennial interest to the electrical engineer was proved by the discussion evoked by Dr. A. Clow's lecture at Savoy Place on the 27th January 1960. With Mr. M. J. L. Pulling in the Chair, Dr. Clow, long experienced as university lecturer, editor, and producer of B.B.C. talks, spoke on 'The oral presentation of scientific material'.

In this scientific age, Dr. Clow began, the popularity of science was an essential part of the new humanism. His task was to present the results of scientific work to an enormous audience, only a small proportion of whom had direct scientific experience or training. What were the main factors affecting the intelligibility of talks about science given to such an audience?

Under the direction of Prof. P. E. Vernon the Listener Research Department of the B.B.C. had established some important facts. Dr. J. Trenaman had analysed the responses of listeners and had been able to specify the most suitable length, form and material content of the talks addressed to various audiences. The work of Dr. W. E. Flood on the intelligibility of scientific terms to school-children had also been of great help. One discovery of listener research was that the understanding of a talk designed for radio was not enhanced by television.

Dr. Clow then described the criteria which he applied in editing scripts of science talks. Having decided that the matrix of material was appropriate, he had to ensure that the language was simple and terse, that all clichés were removed, that the technical terms admitted were correctly explained and used, and that the sequence was coherent. The interest of the listener must be engaged within 30 seconds; the talk must be rounded off firmly and conclusively. In reading the script a lively and natural variation of tone and emphasis was needed.

To 'er' is human

The discussion was opened by Mr. B. C. Brookes who emphasized that the first need of good presentation was to have something to say and a clear purpose in saying it. Undue preoccupation with presentation could lead inexperienced speakers to put form before content and inhibit some, conscious of their defects, from speaking when they should. It could also lead to the belief that there was one ideal form for any talk, whereas he had observed that the same end could be equally well achieved by different lecturers in different ways.

Mr. R. C. Winton asked at what level of intelligence the radio talker should aim. Prof. R. O. Kapp widened discussion by criticizing 'committee manners' and by stressing the importance of breaking the flow of words by an occasional silence.

With apt quotations from Faraday's correspondence Mr. G. Parr condemned the lecturer who 'angles for claps' and deplored the continued decline of lecture demonstrations. Mr. R. T. B. Wynn complained of the distraction caused by the fumbling of slides and of their deficiencies and reminded the audience that in listening to someone 'thinking aloud' they should not forget that 'to "er" is human, to forgive divine'.

The useful work done by the Institute of Radio Engineers on aspects of presentation in recent years was referred to by Mr. C. T. Rivington. He pleaded eloquently for the establishment of a permanent group within The Institution to consider methods of presentation relevant to its interests. Other speakers described the methods recommended in the Committee course at the Northampton College of Advanced

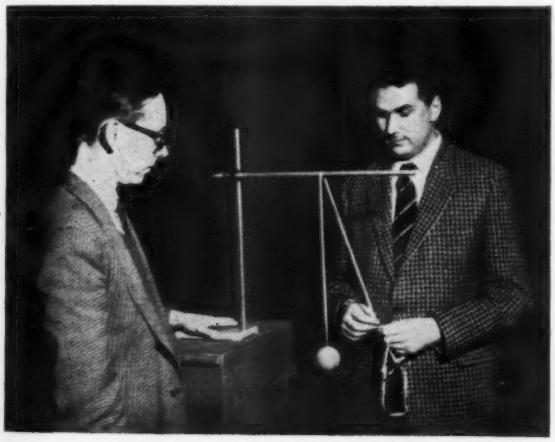
Technology, and suggested the recording on tape of oral reviews of current journals as an information service.

In reply Dr. Clow said that a good editor always encouraged individuality. He asked speakers to address themselves to their 'intellectual but not professional peers'. In closing the meeting the Chairman appropriately acknowledged Dr. Clow's message by belatedly changing the title of the lecture to 'Talking about science'. B. C. B.

Beam-type parametric amplifiers

THE lecture at Savoy Place by Messrs. R. B. Dyott and C. R. Russell on the 29th January 1960, entitled 'Beam-type parametric amplifiers: some aspects of their design and use', was an unusual event in a number of ways. It was given by two lecturers, it dealt with research work being actively pursued at the present time, it made use of unusual methods of presentation and it was held on a Friday! In particular the use of a blackboard to deal with points of detail was replaced by epidiascope projection both of free-hand sketches made by the authors during the lecture and of bibliographical references to current work in the field, which, together with a number of demonstrations, resulted in an atmosphere of special intimacy.

The lecture was opened by Mr. Dyott who outlined some of the principles of parametric excitation, involving the concept of an alternating power source, from Lord Rayleigh's contribution in 1883 (see photograph). These were illustrated, with



Messrs. Dyott and Russell demonstrating the parametrically pumped pendulum suggested by Lord Rayleigh in his 1883 paper

Mr. Russell's assistance, by simple mechanical demonstrations, one of which depicted the alteration from parametric to normal excitation of a vibrating string by change from longitudinal to transverse stimulus (Melde's experiment).

From here Mr. Dyott led on to the most successful form of parametric beam device produced so far, the transverse-field tube due to R. Adler, in which the effect of the inherent axial noisiness of a beam focused by a magnetic field is avoided by the use of transverse energy interchange; the second-order beam-noise currents are absorbed in the resistance of the input circuit. The radius of rotation of the beam around the magnetic field, arising from transverse fields due to the input signal, is amplified by the passage of the beam through further transverse fields generated by a power source, the pump, of frequency approximately twice that of the signal. The increased radius of rotation results in an amplified signal being injected into an output circuit, also coupled by transverse fields. The application of this principle has resulted in an amplifier having a noise factor as low as 1·3 dB at 200 Mc/s.

A daring experiment

At this point a demonstration was given by Mr. A. D. Williams of the low-noise properties of an experimental tube operating at 500 Mc/s. It was shown that, when operated without applied input signal, the output noise signal, due partly to the inherent noise of the input circuit resistance and partly to the amplifier, fell significantly when the input resistance was plunged into liquid nitrogen at 75° K, indicating that the amplifier noise was not the predominating component of the output noise signal. As was pointed out by Dr. E. A. Ash in the later discussion, this was a somewhat daring experiment to carry out in the Lecture Theatre; noise experiments could usually be depended on to behave correctly only when the audience was one in number!

Concluding this part of the lecture, Mr. Dyott indicated that performance at much higher frequency had been achieved, preliminary results having been obtained in the United States at 4 Gc/s. A proposal had also been made to replace the high-frequency fields due to the pump source by d.c. fields, but this arrangement did not appear to have the property of low-noise operation, though it might be considered for high power.

The second part was given by Mr. Russell who outlined work proceeding on another form of parametric beam amplifier, the longitudinal-interaction type proposed by W. H. Louisell and C. F. Quate. He made it clear that it differed in one important respect from the kind described earlier: so far it did not work! Nevertheless the principles involved, which were very new, were of considerable interest in understanding the detailed behaviour of beam-type amplifiers, making free use of the concepts of 'fast' and 'slow' electron beam waves. A fast wave may be removed by absorption and thus, by using only fast waves, the effects of inherent beam noise may be eliminated.

The basic idea involved in this device is that of modulation of the beam by the input signal and amplification of this by mixing with the fast-wave component of a relatively large pump wave. Low-noise amplification is then possible if only signal, pump and difference frequencies are transmitted. A slide was shown of elaborate equipment in which this gain mechanism has been demonstrated, a gain of 5 dB per space-charge wavelength being measured with signal and pump frequencies of 2·5 and 5 Gc/s respectively.

Difficulties occur owing to the inherent wide-band transmission characteristics of the beam, in that beats between appropriate harmonics can result in increased noise and reduced amplification, and consideration is being given to various means of eliminating these effects. The transverse-interaction amplifier described earlier has inherent dispersion

arising from the natural frequency of rotation of electrons around the magnetic field, by means of which these effects are avoided.

In comparing the possibilities of the new amplifiers with those of the established low-noise travelling-wave type in which beam noise is avoided in quite different ways, Mr. Russell made it clear that advances in the latter seemed to indicate that it had at least as good a potential noise and gain performance and had the additional advantage of large bandwidth. A noise figure of 3dB had been obtained in the region of 3Gc/s and further work tended to show that the effects of beam noise could be substantially eliminated.

Magneto-hydro-dynamic generators

The discussion was opened by Dr. Ash who commented among other things on the significance for the generation of the highest frequencies of the proposal to use a d.c. pump field in the transverse-field device. He expressed surprise at the wide range of phase of entrance of electrons to the r.f. pump region for which favourable interaction seemed possible. This point was answered later by Mr. H. W. Tuffill who showed the results of detailed computer calculations from which it appeared that arrival of the electrons over a phase range relative to the optimum of $-83°$ to $+87°$ resulted in favourable interaction in a structure in which the transit time was five periods.

Mr. D. T. Swift Hook enlarged the scope of interest of the meeting by referring to m.h.d. (magneto-hydro-dynamic) generators by means of which powers of the order of 10kW (d.c.) had already been produced. The direct generation of d.c. power is achieved by the flow of ionized gas through a transverse magnetic field, and the interruption of this flow can in principle result in the generation of a.c. power by a process of parametric self-oscillation. This then was another example of a beam-type parametric device.

Mr. J. Dain made a strong plea for the use of noise 'temperature' instead of the more familiar 'factor' and laid particular emphasis on the important aspect of dynamic range of low-noise amplifiers. He observed that in the transverse-field device the output fell to zero with high input and did not merely saturate.

Points made by other speakers referred to the significance of the large noise fluctuations existing in the transverse-beam device even after the transverse component had been removed, and to the need for maintenance of good noise performance over the whole of the amplifying band.

In concluding the meeting, the chairman, Mr. R. J. Halsey, expressed the thanks of all those present to the authors and their collaborators. W. E. W.

SUPPLY

An exercise in switching surges

OVERVOLTAGES or, to use a more familiar term, switching surges are a sporty team of gremlins. They cause the expenditure of much ink and give exercise to the mathematically minded in trying to marshal their mythical bodies into orderly behaviour.

On the 9th December 1959 a paper was presented at Savoy Place on a subject which so far has received very little organized effort.

'Field suppression of turbo-alternators' by Messrs. J. R. Hill, A. Hunt, W. J. Joyce and D. H. Tompsett is a paper with a mathematical approach and practical check tests on a range of turbogenerator sizes up to 111MVA. The interest evoked by this paper was exemplified by the very large attendance and especially by the presence of M. P. Laurent of Électricité de France who made the journey from Paris. The paper is reviewed on p. 169.

Camps and watch-towers

The discussion was opened by Mr. I. W. James. M. Laurent gave a Continental viewpoint. There were speakers from the designers' camp, from the users' camp and from those who sit in watch-towers. It was a good discussion, ten speakers taking part. Mathematics of simpler form than the exposition in the paper was claimed to resolve the problem. The ratio of discharge resistance to hot field resistance was moved up and down the scale. The real gremlin, the over-voltage and the aiding and abetting by the field circuit-breaker, was left to take a back seat, a convenient place for gremlins.

The countenances of the four authors, grouped behind the Chairman, Dr. J. R. Mortlock, taking notes of the points raised were an entertaining study in facial expression. The problems set by the discussion warranted serious concentration; in fact some of the points raised called for deeper reflection than the time permitted in an after-discussion summing-up.

The authors skilfully replied, availing themselves of the option to deal with the discussion in writing. A. C. E.

Gaseous-discharge phenomena in high-voltage d.c.-cable dielectrics

VERY-HIGH-VOLTAGE a.c. cables did not become a practical possibility until the destructive effect of gaseous ionization was recognized and measures were taken to remove all risks of its occurring. In considering the impact of the possible extension of the use of direct current for transmitting large blocks of power at very high voltage and over long distances, the cable engineer has assumed that ionization hazards will be reduced to negligible importance.

The main purpose of the work reported by Mr. E. C. Rogers and Mr. D. J. Skipper at Savoy Place on the 13th January 1960 had been to obtain quantitative substantiation of this assumption and, what is more important from the practical aspect, to indicate the limits to which a d.c. dielectric might be

pressed. Despite the research nature of the paper, many of the points made in it were well taken and enlarged on by cable engineers in the subsequent discussion. An article based on the paper will be found on p. 164.

Although the authors had concerned themselves only with cable dielectrics, some speakers pointed out that the results would be equally applicable to other d.c. equipment. Indeed, the opinion generally expressed was that a significant step forward had been taken into a field which had been left largely unexplored.

Elegance *ad infinitum*

The paper contained a large mathematical section (which, happily for most of the audience, was taken as read!) and mathematicians everywhere would have been amused and, perhaps, heartened had they heard the several remarks to the effect that the treatment must have been correct, if for no other reason than that the result was what an engineer would have deduced by logical processes.

Both the mathematical theory and the experimental technique which had been devised to test it were highly praised by most speakers, and the word 'elegant' was so overworked that those who came late in the discussion felt obliged to apologize for using it. The Section is never at such a loss for adjectives when it is engaged in controversy.

Just recently, a verbal campaign has been launched in the United States to stimulate the chemist and the physicist to set about constructing a new polymeric material, specifically designed for h.v. cable insulation. The first faint echo of this reached across the Atlantic to The Institution on the evening of the meeting, and it may be regarded as certain that more will be heard of the idea. The outcome will be awaited with interest—but it will not be surprising if it turns out to be a very long wait.

A. L. W.

MEASUREMENT AND CONTROL

Philosophical algebra

THE Section met at Savoy Place on the 19th January 1960, with Prof. A. Tustin in the Chair, for a discussion on a.c. bridges in which mutual inductors are used as ratio arms. (These are often called 'transformer bridges' but the Section Committee had cautiously avoided this possibly misleading term.) Mr. C. G. Mayo, whose name deserves to be better known than it is for his work with these devices, had provided an abstract in which he had listed their advantages—in particular their high precision, the ease of 3-terminal measurements and the wide range of impedances which can be covered with only a few standards.

Having set out these and other technical matters in some detail, he felt free, he said, to speak instead about the philosophy of Wittgenstein and some elementary algebra. The philosophical principle seemed to be that everything is quite simple when you have found the right way to look at it; and the algebra concerned the different treatment to be accorded to metrical quantities (which need a statement of the tolerances) and logical quantities (which are exact). Numbers of turns on transformers are exact, and the resulting simplicity of a bridge solution proves that transformer bridges are philosophically desirable.

After this introduction—which it is much easier to caricature than to report with justice—Mr. A. C. Lynch plunged abruptly into purely technical reasons for using these circuits. He described devices which could be employed with them but not with ordinary bridge networks, and certain purposes for which transformer bridges could not satisfactorily be used; and on every one of these points he was contradicted by later speakers. His main recommendation was that these bridges should be employed by the substitution method for measurements of capacitance and resistance, but not inductance. Mr. B. Rogal, however, suggested that substitution methods were used only by people who didn't trust their bridges. He also emphasized the small number of standards needed when variable-ratio transformers were employed.

Unmeasurable precision

The printed abstract had claimed a precision of the order of 1 part in 10^8 (quoting a reference which, as Mr. W. H. P. Leslie pointed out, was less helpful than one would have hoped), whereas that of the most familiar commercial transformer bridge is thought to be about 1 part in 10^5. The contrast between these claims attracted the inquisitive attention of Mr. Hill and Mr. G. H. Rayner who both wanted to know how the precision could be measured. Mr. Hartley had faced a similar problem when using tapped transformers as potentiometers for the control of machine tools, and found it almost insoluble. (Your reporter hopes that, on some future occasion, Mr. Hartley will describe his work at greater length.) Mr. Mayo's reply was of startling simplicity and was unassailable yet unsatisfying: no check of the accuracy is possible, because no other circuit is precise enough for checking it.

Although Mr. Mayo's abstract had shown his willingness to construct transformers for frequencies up to 1000 Mc/s, there was surprisingly little discussion on this point. Mr. M. J. Gay, however, explained the difficulties of keeping the connecting leads short enough at the higher frequencies, concluding that the only satisfactory arrangement would be to have all the bridge components coincident in space.

Contributions of a more theoretical kind came from Mr. Calvert who deduced the bridge solution from first principles, emphasizing that what were really being measured were not impedances but voltages and currents, and from Mr. J. W. Head who warned us that, if we *must* divide by zero, it had better be a metrical and not a logical zero.

The subject was a well defined one and the Section was fortunate in finding so many of its members equipped to discuss it. The result was a discussion remarkable for the number of relevant and well informed contributions and also for the ample and welcome use made of the blackboard.

A. C. L.

UTILIZATION

Dinner-Dance

On the 15th January 1960 at the Café Royal, London, Mr. and Mrs. T. E. Houghton welcomed a record number of 250 to the Section's Annual Dinner-Dance.

They were delighted to have with them Sir Willis and Lady Jackson, Dr. and Mrs. J. R. Mortlock from the Supply Section, Mr. and Mrs. J. K. Webb from the Measurement and Control Section, and Mr. and Mrs. R. J. Halsey from the Electronics and Communications Section.

The combination of congenial company, good food and wine, music and dancing ensured an excellent occasion.

News from the Centres

NORTH MIDLAND CENTRE

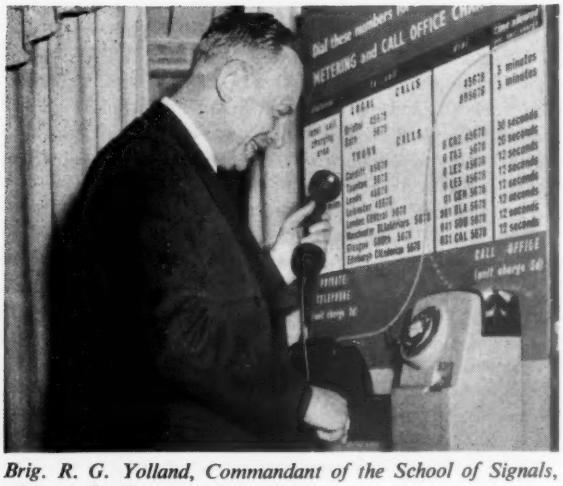
Catterick District Meeting

The subject of the first meeting of the new session on the 13th October 1959 was the paper by Mr. D. A. Barron 'Subscriber trunk dialling'. An article based on the paper was published on p. 236 of the April 1959 *Journal*.

The District Convener, Lt.-Col. M. A. Philp, welcomed Prof. G. W. Carter, Chairman of the Centre, and asked him to welcome Maj. M. R. Ridler as a new Corporate member. This was the first ceremony of enrolment at a Catterick District Meeting.

Mr. Barron introduced his topic with an effortless charm and fluently described the interesting developments that are soon to provide a new system of communication throughout the country. His demonstrations were vivid and entertaining. In the style of their new equipment the Post Office engineers have maintained the elegance of their engineering techniques. A lively discussion followed, and it soon became clear that persuading the public of the justice of the costing arrangements is by no means the least of the engineers' difficulties.

In thanking the lecturer, Lt.-Col. Philp called the attention of the meeting to the modernity of the Post Office in its continual efforts to improve traditional methods without sacrificing the benefits of capital equipment already installed.



Brig. R. G. Yolland, Commandant of the School of Signals, tries out the demonstration equipment

Low-pressure resins

The second Ordinary Meeting was notable for a critical discussion by several of the 40 members and guests present. After Prof. Carter had welcomed two new Corporate members, he introduced Mr. W. Gray and Mr. K. Rothwell and invited Mr. Rothwell to read the paper entitled 'The application of low-pressure resins to some high-voltage switchgear designs' of which they are joint authors with Mr. T. R. Manley. The paper was reviewed on p. 26 of the January 1960 *Journal*.

The number of contributions to the discussion showed the wide interest taken in the subject, and a hearty vote of thanks was accorded to Mr. Gray, who replied to the discussion, and to Mr. Rothwell.

Annual Dinner

About 280 members and guests were present at the Annual Dinner in the Queen's Hotel, Leeds, on the 20th November 1959. In proposing the toast of The Institution Maj.-Gen. E. S. Cole, Director of Telecommunications, War Office, said he had had close associations with The Institution since 1924. He had been very pleased when the enthusiasm of a few officers and the co-operation of the Centre had resulted in the formation of the successful Catterick District.

Replying, Mr. A. H. Mumford, a Vice-President, referred to the increasing membership and sphere of activities of The Institution; since the recent war the membership had increased by 45%. He was very glad to hear from Maj.-Gen. Cole that the Services appreciated that The Institution was trying to co-operate and offer all the help it could. Prof. Carter welcomed the guests in a gracious and intimate speech illustrated by suitable quotations. His toast was responded to by the Very Rev. Llewellyn Hughes, Dean of Ripon, in a most delightful and witty manner.

Utilization Group

The programme for the first half of the 1959–60 Session consisted of two meetings, the first held in the Conservative Club, Leeds, and the second in the Electrical Engineering Lecture Theatre, University of Leeds. The Group, like the Centre, is at present without a permanent home. Fortunately the fluctuating venue has had no adverse effect on either attendance or enthusiasm.

On the 20th October 1959 our new Chairman, Mr. G. Auton, was installed with suitable ceremony. There followed

Personalities at the Annual Dinner of the North Midland Centre on the 20th November 1959

Left to right: Mr. A. J. Coveney, Mr. W. J. A. Painter, the Very Rev. F. Llewellyn Hughes, Mr. J. D. Nicholson, Prof. G. W. Carter, Maj.-Gen. E. S. Cole, Mr. A. H. Mumford, Mr. G. N. Patchett

the reading of Mr. E. Jacks's paper on 'Discrimination between h.r.c. fuses'. A good discussion was contributed to by 12 speakers.

The meeting on the 17th November 1959 was the occasion of an informal discussion on Mr. E. E. Jacobi's paper 'The provision of adequate electrical installations in commercial buildings'. Thirteen members discussed the paper in some detail.

Automatic recognition of patterns

Thirty-one members were present when Prof. Carter opened the third Ordinary Meeting on the 24th November 1959 and introduced three new Corporate members. The paper entitled 'A system for the automatic recognition of patterns', presented by Mr. F. W. Sumner, proved to be a most interesting discourse on an unusual topic. Many questions were asked and, in thanking the author, the Chairman said they were deeply grateful for an intriguing paper right out of the usual line.

Arc initiation and power-follow current

The fourth Ordinary Meeting on the 15th December 1959 was notable for a highly technical and critical discussion on arc initiation and power-follow current after the presentation of two papers by Dr. L. L. Alston: 'The impulse initiation of arc discharges' and 'Investigations of power-follow-current phenomena using a synthetic power source'.

After a very competent reply to the discussion, the Chairman, Prof. Carter, in proposing a vote of thanks, made reference to remarks in the discussion about the use of new terminology and said that they could not complain that a paper was complicated when the investigation itself was so intricate.

H. H.

MERSEY AND NORTH WALES CENTRE

Annual golf tournament

THE annual golf tournament of the Centre will be held at Ainsdale on Tuesday, 21st June 1960, by the invitation and generous co-operation of the Southport and Ainsdale Golf Club. Although this championship course has twice been the scene of a Ryder Cup match, the Centre handicapping committee are famed for their benevolence. The tournament will be a full-day event open to members and their friends and includes an 18-hole singles, a greensome of 14 holes, and putting competitions.

Entry forms may be obtained from Mr. G. L. Simpson, c/o A. Reyrolle and Co. Ltd., 453 India Buildings, Liverpool 2.

E. W. A.

SCOTTISH CENTRE

1899–1959

ON the 14th December 1899 the Council agreed to the formation of the first local Sections of The Institution in Glasgow, Newcastle and Dublin. Glasgow was the first to hold a formal meeting, on the 18th January 1900, when Mr. Alexander Siemens, Past-President, and Prof. John Perry, Vice-President, were said to have intended to make the journey to help to inaugurate the Section. Unfortunately, detailed records of this meeting seem to have been lost.

The Glasgow Section subsequently grew into the Scottish Centre which, as part of its Diamond Jubilee celebrations this session, held a conversazione on the 28th January 1960. As the Centre was born in Glasgow, and as Lord Kelvin, Professor of Natural Philosophy at the University of Glasgow, was its first Chairman, there could hardly have been a more appropriate place for holding the conversazione than the Bute Hall of Glasgow University. Members and guests, including a group from Newcastle and from several other Centres, were received by Mr. J. A. Aked, Centre Chairman, and Mrs. Aked and by the President and Lady Jackson.

Exhibits of modern and historic engineering equipment were displayed and some fascinating films of old Glasgow were shown; in the course of the evening Mr. Aked formally presented to The Institution a signature desk, bearing the Scottish Thistle, for use, along with a similar desk given by the North-Eastern Centre, at the main entrance to the reconstructed Lecture Theatre at Savoy Place. The President accepted the gift on behalf of The Institution and, in thanking the members of the Scottish Centre for their generosity, wished the Centre every possible success during its next 60 years.

E. O. T.

NORTH STAFFORDSHIRE SUB-CENTRE

Joint Annual Dance

THE Joint Annual Dance held at Stone on the 13th November 1959 again provided a most enjoyable social evening. Although on this occasion the number present was lower than in recent years it was gratifying to see the considerably increased support by Graduates and Students who are now also taking a greater share in organizing the dance. The Chairman, Mr. A. Asbury, presented the prizes won by dancers and thanked all who had assisted with the arrangements.

As we are not prepared to accept that the date, Friday the 13th, had any adverse effect, we believe that the reduced attendance was mainly due to another function held on the

same evening which many of the senior members had to attend. The date for our dance has to be selected about a year in advance and is thus known in good time, but it is understood that the organizers of the other event were unable to prevent clashing with us on this occasion. In the hope of avoiding this and other counter-attractions next session, the Committee intend to bring the date of the dance forward to the 28th October 1960.

Field suppression of turbo-alternators

The meeting at Stafford on the 16th November 1959 was honoured by a visit from Mr. C. T. Melling, a Vice-President, who presented the greetings of the President and Council. He said the Council and its proceedings often seemed to be rather remote from the general membership, although we might not feel this so much as we had local Sub-Centre members on the Council. Although the Council is truly representative of the whole country, this impression of remoteness is appreciated, and methods of achieving closer contact are being considered. An account in the *Journal* of the Council's work should assist in this.

Mr. Melling mentioned that, while papers submitted tended to become ever more specialized, there was a great demand for those of a more general character such as that to be presented that evening. He concluded by thanking members for their increased contribution to the Benevolent Fund and asked for still further support for the good work being done.

The Chairman regretted that two of the authors of the paper to be read, Mr. W. J. Joyce and Mr. D. H. Tompsett, were unable to be present but welcomed Mr. A. Hunt and Mr. J. R. Hill and invited them to deliver 'Field suppression of turbo-alternators' which outlined the theoretical and experimental considerations involved in the design of field-suppression circuit-breakers and discharge resistors for large machines. The paper is reviewed on p. 169 (see also p. 194).

In opening the discussion Mr. K. Love remarked that the d.c. circuit-breaker was the Cinderella so far as circuit-breaker testing was concerned and he congratulated the authors on their work in this direction. He thought that, while the demand for d.c. breakers was not great, the duty imposed on them was often onerous and it was important that they should be adequately tested. Many other members contributed to the discussion, to which the authors fully replied.

Mr. W. T. Warnock proposed a vote of thanks to the authors and congratulated them on their excellent presentation of the paper and the admirable way in which they had dealt with the many difficult questions.

Discrimination between h.r.c. fuses

At Stoke on the 11th December 1959 Mr. E. Jacks read his paper 'Discrimination between h.r.c. fuses' (reviewed in the May 1959 *Journal*, p. 304) in which he described the principles on which discrimination depends and their application in practice. As tests to ascertain the characteristics of fuses involved their destruction, fuses used in service must be manufactured to a high standard of consistency which required careful quality control but was also dependent on simplicity of design.

The discussion was opened by Mr. L. Goodall who referred to the 'Z' fuse in use over 40 years ago as the apparent forerunner of the modern h.r.c. fuse. He also ascertained from the author that the accuracy of manufacture was such that the tolerance bandwidth relating to the characteristic curves would be of the order of $\pm 5\%$.

During the discussion some of the questions were outside the scope of the paper, and reference was made to this in a wittily proposed vote of thanks by Mr. R. W. Palmer who stated he had enjoyed listening to the author trying to keep members to the subject of the paper, discrimination, but completely failing. The author had therefore gone all round the topic, and the result had been very interesting. He complimented him on presenting an apparently simple device with rule-of-thumb characteristics and explaining so clearly all that lay behind it.

Before closing the meeting, the Chairman directed the attention of members to the danger inherent in some imported domestic electrical equipment of which the flexible connections were made to a colour code different from that used in this country and particularly referred to the use in some cases of the red core as the earth wire. L. G.

News from abroad

TRINIDAD AND TOBAGO JOINT GROUP

Annual Dinner

As usual, the New Year opened with our Annual Dinner which was again held at the Queen's Park Hotel in Port-of-Spain.

Over 135 members and their guests—a record number—gathered for cocktails before dinner. A fanfare played by the trumpeters of the Trinidad Police Band announced the arrival of His Excellency the Governor, Sir Edward Beetham, shortly after which those present took their places in the dining-room. Apart from His Excellency, the principal guests were the Hon. Learie M. Constantine, Minister of Works and Transport; Sir Courtenay Hannays, Q.C., representing the Bar Association; and Dr. A. L. Down, the Chairman of the Institute of Petroleum.

Following the loyal toast, the Hon. Learie Constantine proposed the toast of the institutions and dealt at some length with the need for engineers in the rapidly developing economy of the island. The Chairman, Mr. W. T. Boyd, M.I.MECH.E., replied and dealt with some of the major engineering achievements of the past year. Mr. A. H. Richard then welcomed the guests, Sir Courtenay Hannays responding in a delightfully witty speech.

After dinner the Trinidad Police Band played music for dancing, and a very pleasant evening finished at 12.45 a.m.

Following the appointment as Programme Secretary of Mr. D. Key, A.M.I.C.E., a very full programme has been arranged for 1960. D. P. J. H.